SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Detergents and Activated Sludge—Degens et al.

Industrial Waste Acceptance to Sewers—Estrada et al.

Industrial Waste Regulations—Heukelekian and Orford

Oxidation of Phenolic Wastes—Lynn and Powers

Bacterial Data Interpretation—Pomeroy

JANUARY, 1955—VOL. 27, No. 1

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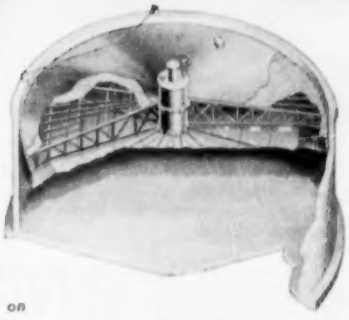

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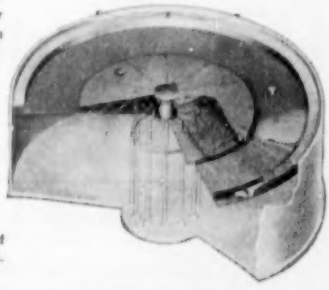

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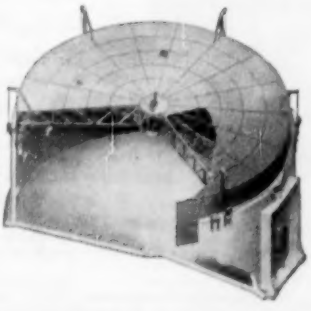

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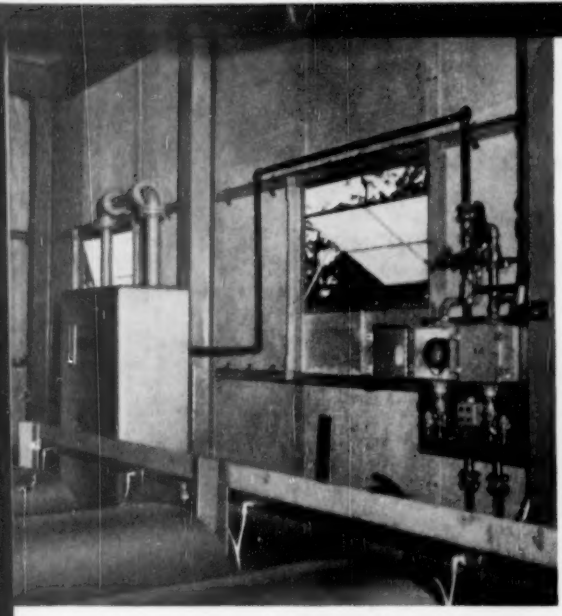
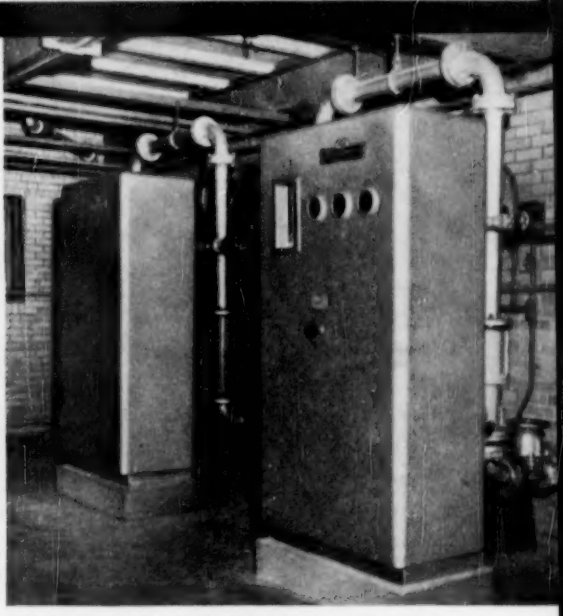


One of the two temporary chlorinating stations which served the Blackstone Valley Sewer District during the interim disinfection period. One of the Builders Chlorinizers can be seen in the background.



Builders Model HCVS Chlorinizers as finally installed in the Bucklin Point Sewage Treatment Plant in East Providence, R. I. Control can be automatic and proportional to flows of the plant influent flumes.

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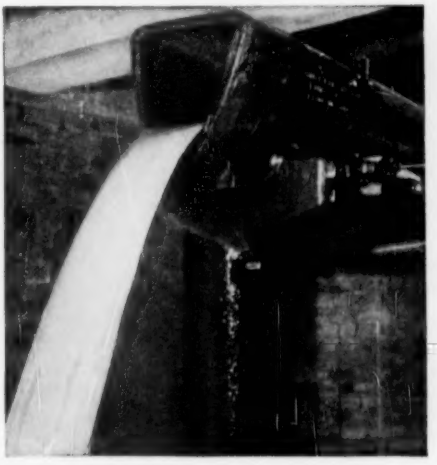

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Association	*Place*	*Time*
New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza, New York, N. Y.	Jan. 20–21, 1955
Texas Water and Sewage Works Assn.	Texas A. and M. College, College Station, Texas	March 6–11, 1955
Kansas Sewage and Industrial Wastes Assn.	Baker Hotel, Hutchinson, Kan.	April 13–15, 1955
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	April 14–16, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955
Montana Sewage and Industrial Wastes Assn.	Finlen Hotel, Butte, Mont.	April 28, 1955
Ohio Sewage and Industrial Wastes Treatment Conf.	Deshler-Hilton Hotel Columbus, Ohio	June 22–24, 1955
Iowa Sewage Works Assn.	Hotel Waukonsa Fort Dodge, Iowa	Sept. 7–9, 1955
Kentucky–Tennessee Industrial Wastes and Sewage Works Assn.	Phoenix Hotel Lexington, Ky.	Sept. 12–14, 1955

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in conjunction with

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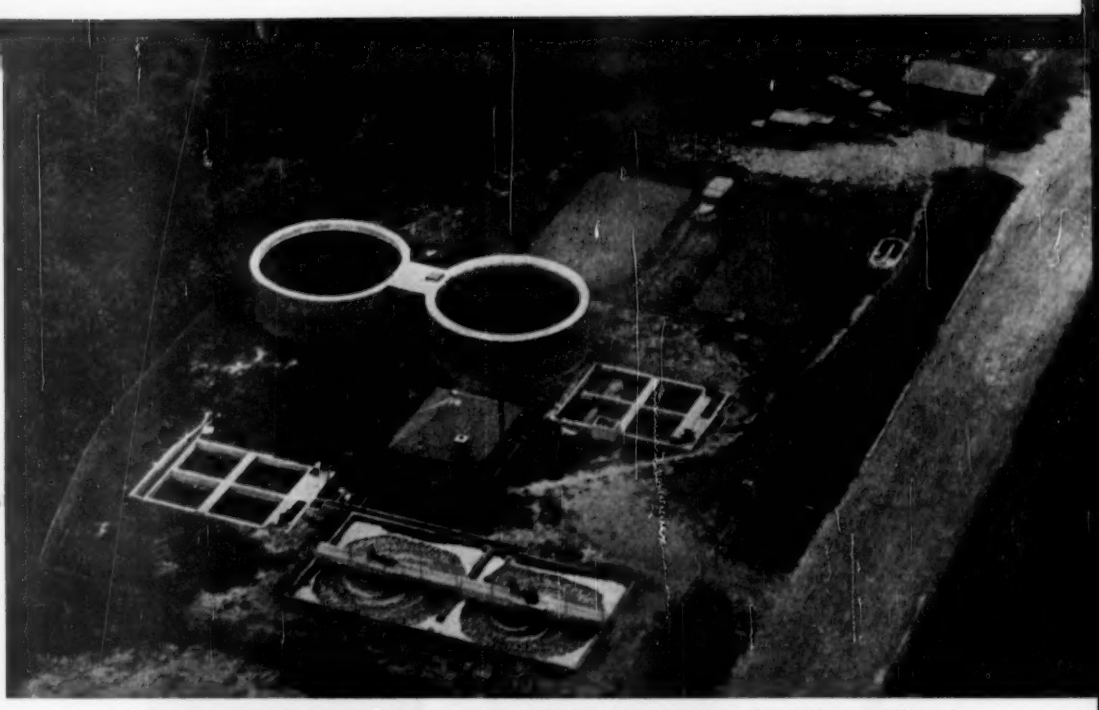
Ambassador Hotel, Atlantic City, New Jersey

October 10–13, 1955



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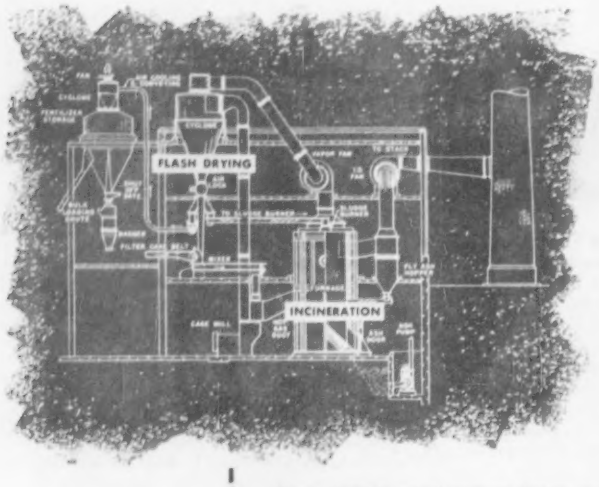

SOME FACTS ABOUT THE HEAT DISPOSAL of SEWAGE SLUDGE

Even though dried sewage sludge can often be sold at from $5.00 to $20.00 a ton — remember that is not *always* the case.

If sewage is contaminated — with grease, fibre, etc., for example — you may find the *only* thing to do is to incinerate the sludge. On the other hand, even though the sludge may not have the highest chemical analysis for fertilizer — it still can be marketed as a soil conditioner — thereby eliminating the ash disposal problem.

The C-E Raymond System of Flash Drying and Incineration is the most popular . . . most versatile on the market today. That's why you will find a C-E Raymond System to provide one or all of the following processes . . . controllably, accurately, economically:

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C-E Raymond Systems now in service or on order serve an equivalent population of more than 17,000,000 people — in communities ranging from 6,000 to 3,600,000 in population . . . in every section of the country, and even overseas.

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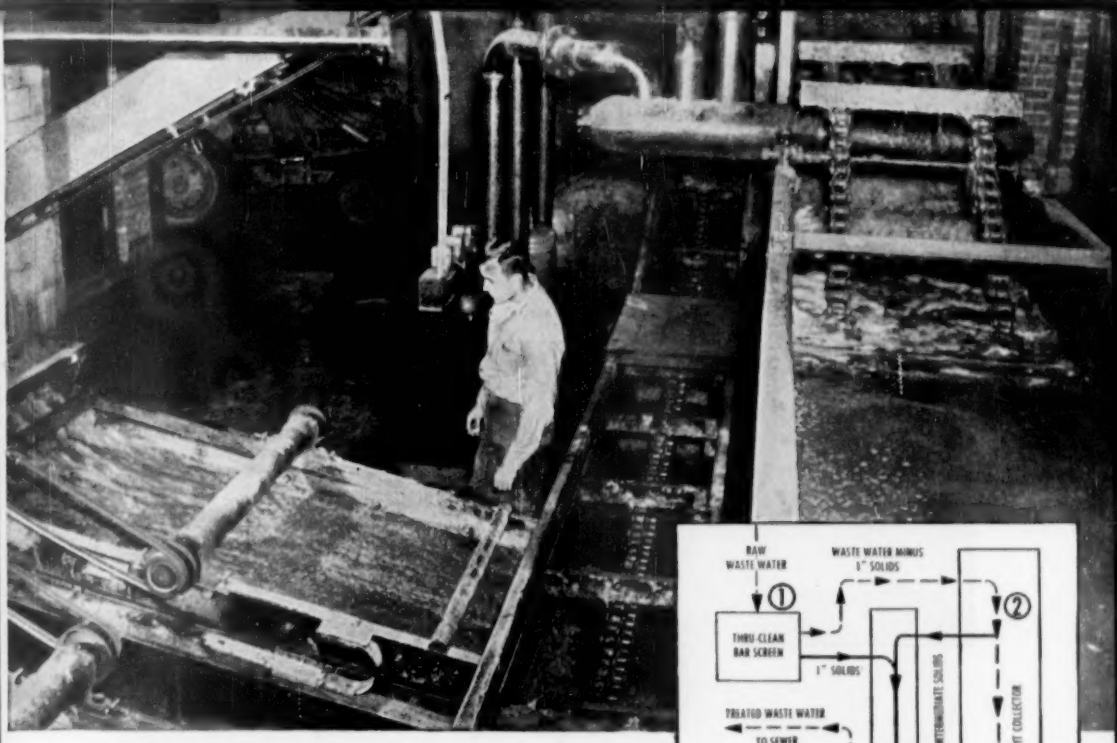
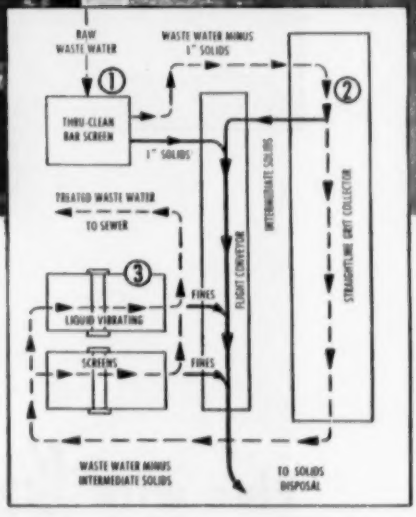
ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL





Lakeside's waste water passes through a Link-Belt Thru-Clean Bar Screen (1), where over-1-in. solids are removed and chuted to the Link-Belt Flight Conveyor. The effluent next goes to the Straightline Grit Collector (2). Here grit and canning wastes that settle out are discharged to the flight conveyor. The water then flows over two Link-Belt Liquid Vibrating Screens (3), where the last of the objectionable solids are separated and the waste water is piped to the sewerage system.

Here's how one plant cleans up its waste water

Compact, efficient LINK-BELT treatment equipment installed at Wisconsin cannery

LIKE many other plants, Lakeside Packing Co. of Manitowoc, Wis., had a problem of how to remove waste from its wash water before discharging it into the municipal sewerage system. And, just as many others have done, they called in Link-Belt engineers.

The efficient Link-Belt system now employed removes solids from the water in three stages at a peak rate of 24,000 pounds a year. This waste is trucked away to be used as fertilizer and feed.

There are other benefits of a Link-Belt waste treatment system. Your waste water may be carrying valuable material down the drain or clogging your sewers. No matter what your problem, Link-Belt experience and equipment assure the system best suited to your needs. Call the Link-Belt office near you for complete information.

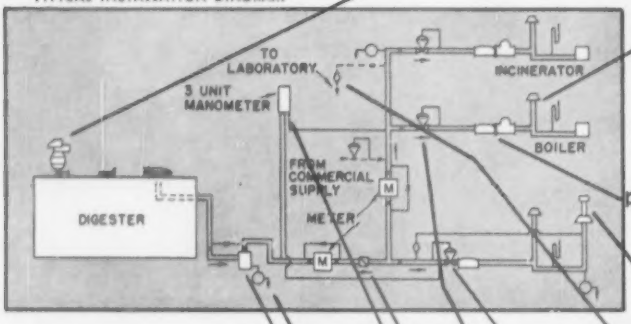
19,462

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70 — Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check —Fig. 51A or 52A— Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 —Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve —Fig. 211 or 211A— Controls direction of gas flow.

"VAREC" Manometer —Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap— Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

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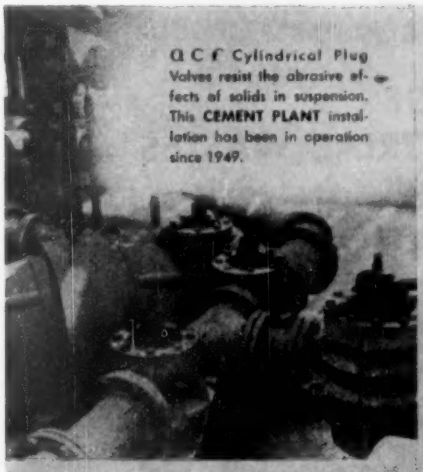
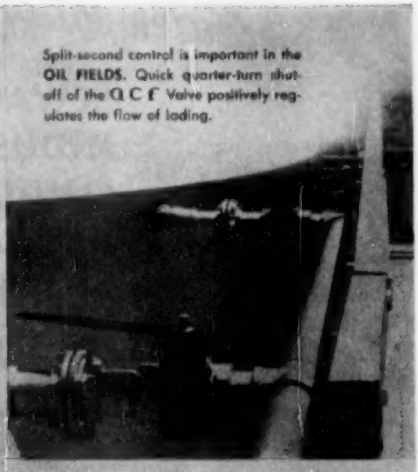
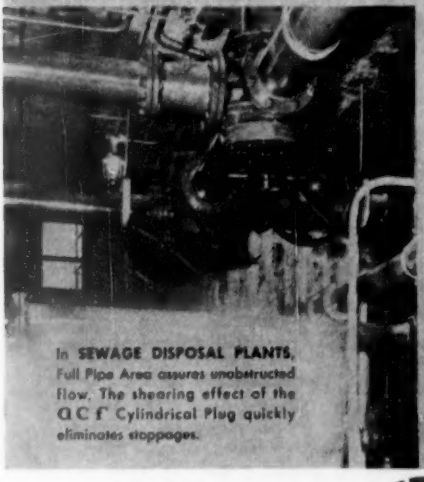


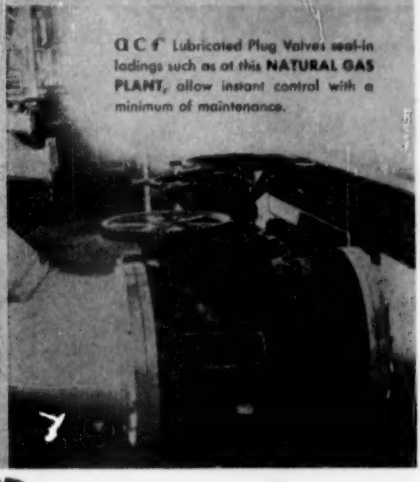
acf Cylindrical Plug Valves resist the abrasive effects of solids in suspension. This **CEMENT PLANT** installation has been in operation since 1949.



Split-second control is important in the **OIL FIELDS.** Quick quarter-turn shut-off of the acf Valve positively regulates the flow of lading.



In **SEWAGE DISPOSAL PLANTS,** Full Pipe Area assures unobstructed flow. The shearing effect of the acf Cylindrical Plug quickly eliminates stoppages.



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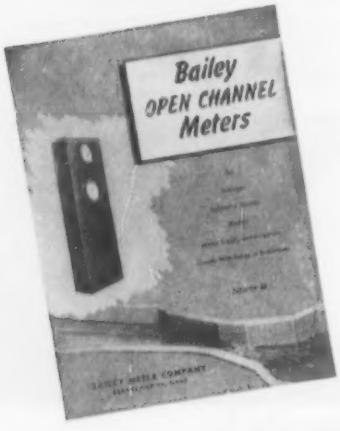

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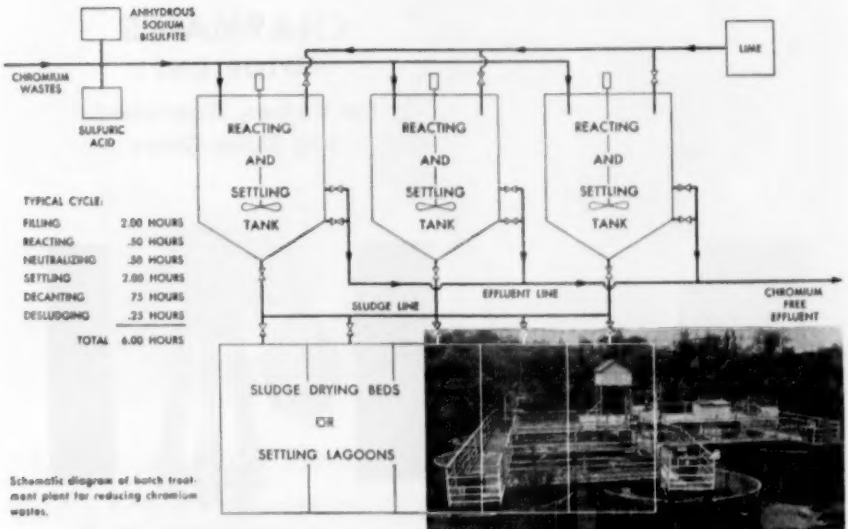

Schematic diagram of batch treatment plant for reducing chromium wastes.

Batch plant giving efficient removal of chromium waste at the Electrolux Corporation, Old Greenwich, Conn.

Toxic chromium wastes are simply yet effectively and economically treated and neutralized when you use General's Anhydrous Sodium Bisulfite. And it doesn't matter whether the volume to be treated is large or small! Learn the full facts and details . . . call General Chemical's nearest office for skilled assistance and helpful Technical Service in solving *your own* particular problem.

General Chemical has a broad, *practical* knowledge in planning chromium waste installations gained the country over. This knowledge is *yours*—without cost or obligation! For a start—get General Chemical's helpful *free* booklet on the treatment of chromium wastes. It offers sound information on the type of disposal system required, quantities of chemicals involved, operation and control of the system, etc.

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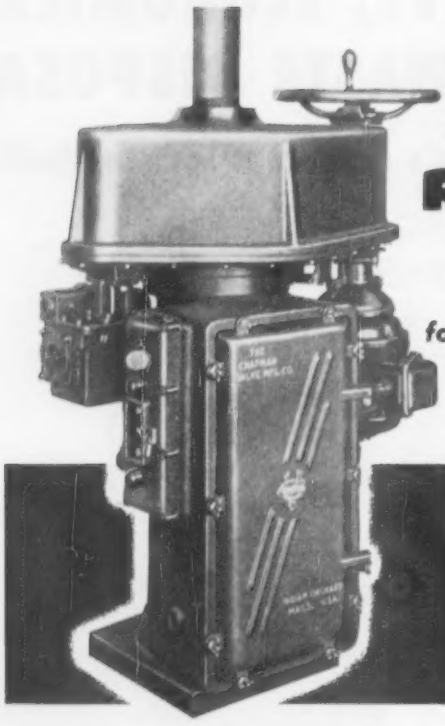

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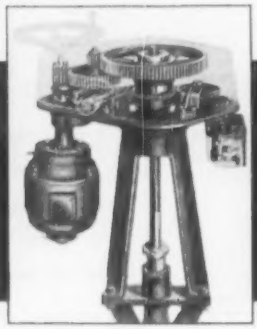
CHAPMAN'S MOTOR UNIT

for Valves, Floorstands and Sluice Gates



Floorstand equipped with Motor Unit . . . control panel, motor, limit switch and push button station.

Simple, durable mechanism of Chapman's Motor Unit. Handwheel remains stationary during motor operation.

Chapman Motor Units have fewer components than any other units, providing greater dependability, much lower maintenance costs.

There are only two pinions and two gears in the motor reduction train: drift is eliminated and lash is negligible. Your valves seat tight, but not too tight. Operation is *always* smooth and trouble-free.

You can mount the Chapman Motor Unit in any position, at any angle required. The rugged stub-tooth gears require no grease or oil bath . . . yet run smoothly, quietly, with minimum wear.

Weatherproof and steam tight, Chapman's floorstand units are shipped completely wired, ready to connect to your power leads, for easy, rapid installation. This modern motor unit is dependable and economical. Send for *new* catalog No. 51.

The CHAPMAN Valve
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Make use of the Unique Advantages of WELSBACH OZONE in Solving Them

If the presence of phenolic compounds in industrial waste is a problem to you and your community . . . and complete destruction is required . . . you should investigate—right now—the economical and dependable solution of that problem by low-cost Welsbach Ozone treatment.

Investigations have shown that chemical oxidation with Welsbach Ozone can provide an *economical* and *complete* answer to the problem of removing phenols from industrial waste.

In addition to its relatively low cost, Welsbach Ozone treatment offers other unique and important advantages:

1. Ozone-phenol reaction is instantaneous. End products are non-toxic. Objectionable tastes and odors do not reappear when water is chlorinated.
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5. Maintenance costs are negligible. And since the only raw materials needed are electricity and air or oxygen, operating costs are constant and predictable.

. . . but, most of all, Welsbach Ozone is economical, convenient and dependable. Write today for information and, if you wish, indicate the nature of your problem. The Welsbach Corporation, Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

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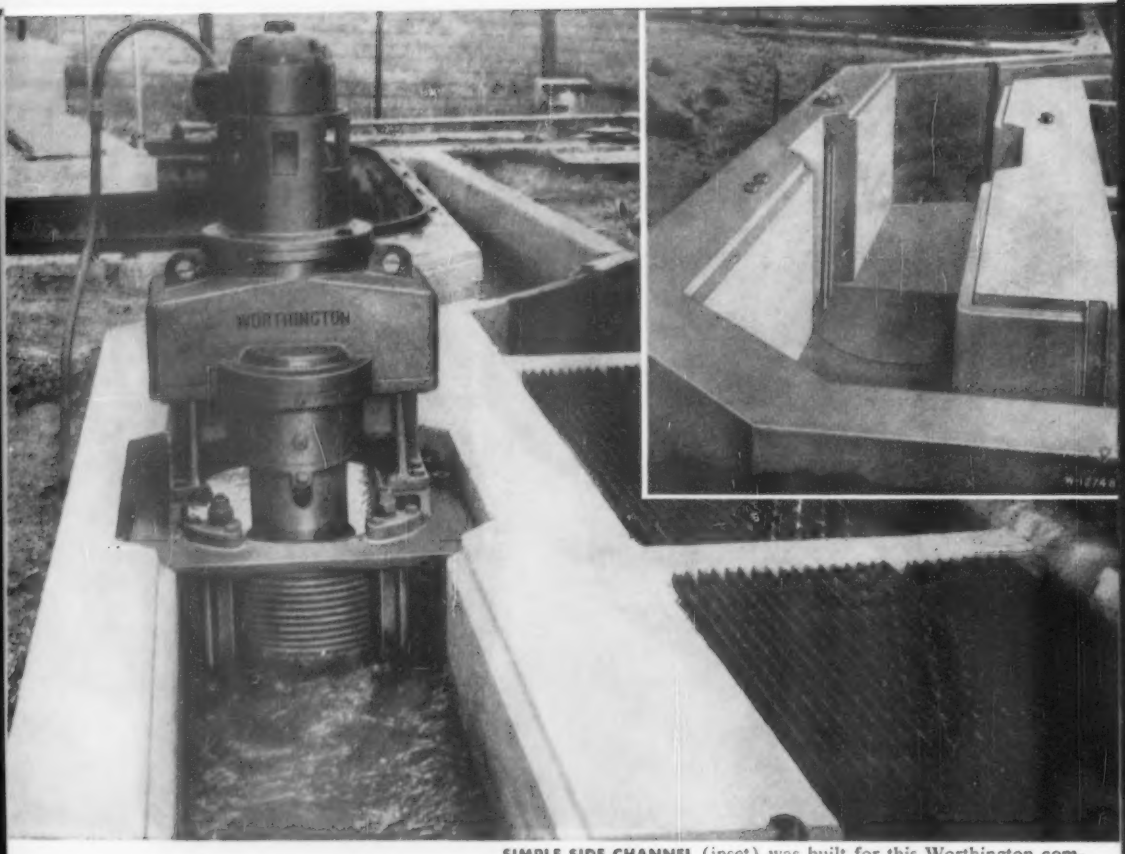
LOW COST • DEPENDABLE



SIMPLE SIDE CHANNEL (inset) was built for this Worthington comminutor at Klamath Falls, Oregon, because Mr. E. A. Thomas, the City Engineer, wanted to use the existing channel as a by-pass.

Low installation cost swings Klamath Falls to Worthington

Since the Worthington comminutor is designed so that raw sewage flows straight through its screen, it's easily installed in a straight rectangular sewage channel.

Result? Expensive masonry work is not needed, which makes for simplified, low-cost installation.

This was an important factor in the selection of a Worthington 25C6 comminutor as part of recent improvements at the Klamath Falls, Oregon, Sewage Treatment Plant.

This comminutor, installed downstream from a grit chamber and upstream from a clarifier, was lifted directly from its packing crate and set right in the channel in a minimum of time.

Easy-to-remove cutter racks for occasional sharpening and the built-in flood protection provided by a mercury seal are other advantages of the Worthington comminutor.

Get all the facts and figures on the rugged Worthington comminutor. Check with your nearest Worthington district office. Or write today for new engineering manual on comminutors, W-317-B17. Worthington Corporation, Public Works Division, Harrison, N.J.

W.4.3

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Armco ASBESTOS-BONDED Pipe was selected for this sewer because it will carry corrosive industrial sewage. Millions of asbestos fibers are bonded to the base metal by a zinc coating and sealed with a special bituminous saturant. The result is complete protection against severe corrosive conditions.

This, plus the flexible strength of corrugated metal design and tight, positive joints, adds up to years of trouble-free service. There is no danger of crushing, cracking, disjointing or malalignment. Quick, simple installation assures low first cost.

You can get Armco ASBESTOS-BONDED Pipe, or for limited headroom applications, ASBESTOS-BONDED Pipe-Arch in a wide range of sizes. Write us for full data. Armco Drainage & Metal Products, Inc., 3515 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.

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REMOVE GRIT

Easily—Thoroughly—at Low Cost

COMPLETE EQUIPMENT

to do the complete job!

PROVIDES CONSTANT OPTIMUM VELOCITY
POSITIVE ADJUSTMENT FOR VARYING FLOWS
HYDRO-DYNAMIC WASHING
AUTOMATIC DRAINING AND REMOVAL

FLOW CONTROLS—exclusive Camp Channel Section and Regulator* maintain constant optimum velocity for effective grit settling, regardless of rate of flow through plant. Velocity can be easily and instantly adjusted to meet changing conditions. Minimum head loss.

*Patented

CONVEYOR—single strand, continuous drag type. Flights carry the settled grit from channel bottom to hopper for washing and removal.

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ELEVATOR—totally enclosed, tube type, for slow and continuous removal of washed grit from the hopper. Grit drains as it is being elevated through the tube.

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Technical Supplement "CR", containing complete design data on the AMERICAN CAMP GRIT CHANNEL *and* REGULATOR, *is available on request with Bulletin 249B.*

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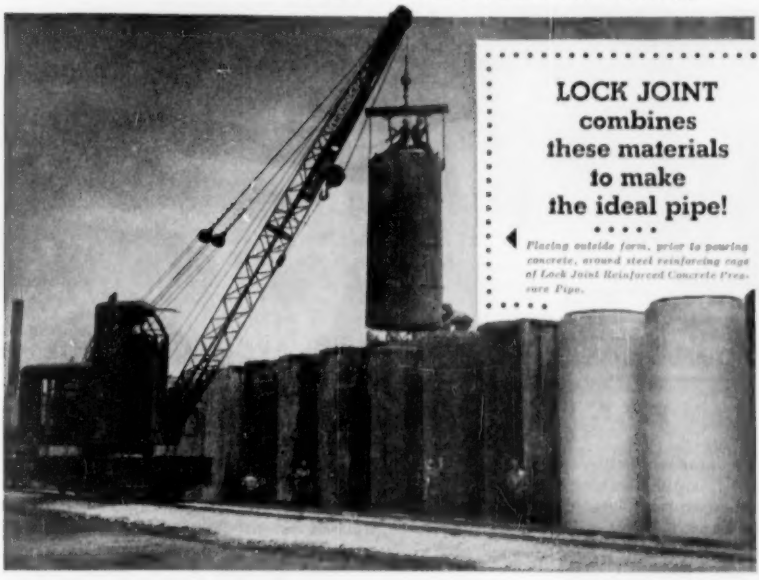

LOCK JOINT combines these materials to make the ideal pipe!

Placing outside form, prior to pouring concrete, around steel reinforcing cage of Lock Joint Reinforced Concrete Pressure Pipe.

CONCRETE, with its proven qualities of durability, non-corrosion, resistance to electrolytic action, and high compression strength is combined, by Lock Joint, with steel's toughness, resilience and high tensile strength to make a pipe that retains the best qualities of both—non tuberculance, high structural strength and long life with little or no maintenance. Dense concrete affords complete protection for the quality reinforcing steel. Both materials are carefully calculated to meet your pressure needs with a wide factor of safety. The Lock Joint Pipe Company's Rubber and Steel Joint is extremely watertight and, at the same time, flexible.

For superior strength, carrying characteristics and trouble-free operation, let Lock Joint supply your pipe needs in sizes 16" and larger.

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operability in a control room layout designed for

P.F.T. "CONTROLLED DIGESTION" SYSTEM

This modern control room is part of a well-designed sewage treatment plant rushed to completion in connection with the Fairless Plant of U.S. Steel. The plant was planned for flexible capacity and simple operation with P.F.T. "Controlled Digestion" equipment.

The control chamber is ideally housed . . . surrounded by the four 55-foot digesters. *P.F.T. Cover Position Indicator Dials* (with low-level alarms) flank each side of the room. An operator may see the exact position of the *P.F.T. Floating Covers* on his tanks at a glance. He may keep close control of supernatant liquor by means of the *P.F.T. Supernatant Selectors and Gauge Glass* located just below the indicators.

Ample space is provided in the control room for convenience in operation of the digester system.

The gas-fired *P.F.T. Heater and Heat Exchanger* (at left) has a capacity of 750,000 Btu per hour. The other unit (at right) is gas and oil fired with a 500,000 Btu per hour capacity. The entire plant incorporates the latest thinking in plant and control room design.

Modern safety features include these P.F.T. Gas Safety Units—two 3-inch waste gas burners; four 3-inch pressure relief units; four 3-inch low-pressure checks; four 3-inch sediment traps and accumulators; flame cells; manometers and drip taps. The gas safety equipment is located in a separate room.

Complete information on all or part of Levittown's equipment is yours upon request.

Outside view of the four 55-foot digesters showing the convenient position of the control room.

Design of plant by | *Albright & Friel, Inc., Philadelphia, Pa.*

P.F.T.

waste treatment equipment exclusively since 1893

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 27 **January, 1955** **Number 1**

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Sewage Works

EFFECT OF FLUORIDE CONCENTRATION ON SLUDGE DIGESTION

By Werner N. Grune and Robert Q. Sload

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Fluorides are finding their way in ever increasing numbers into public water supplies. Because they are not destroyed in the normal course of domestic water consumption, some fluorides will be found in the waste waters, in sewage treatment plants, and to a lesser degree in the sludge. The investigation reported here is a portion of the research work reported in another paper (1) and concerns the effects on sludge digestion due to the fluoride ion.

Since many American cities are, or will be, adding approximately 1 p.p.m. of fluoride ion to their water supply, it was assumed that up to 50 per cent of this concentration, or 0.5 p.p.m., may be found in the sludge. It is known that some substances when present in small quantities may exert a stimulating effect on a reaction, but may be decidedly deleterious to biological or biochemical systems at higher concentrations. Furthermore, Rudolfs (2) suggested that a detrimental effect may be expected with certain salts and chlorine, among others, when present in sludge in more than trace amounts.

Although a normal concentration not to exceed 0.5 p.p.m. of fluoride ion is estimated, almost 5 p.p.m. of sodium fluoride (NaF) as the fluoride ion (F) were added to digester No. 12 in the two runs here presented. The sludge sample size and physical set-up have been described previously (1). Digester No. 11 received no fluoride, but contained the same substrate as No. 12 and served as the control in these experiments. The sludge mixture investigated was in the ratio of 1.5 : 1 raw to digested solids, by weight, based on the initial volatile matter content; the incubation temperature was 30° C. NaF was added only on the first day, since batch digesters were used and any greater concentration of fluoride in a sludge could be only accidental.

The cumulative gas production in the presence of about 10 times the expected normal fluoride concentration appears unaffected, as shown in Figures 1 and 2, digesters No. 11 and 12. The total cumulative gas production in Run IV, using 1,000-ml. sludge samples, was 490 c.c. per gram of volatile solids with almost 5 p.p.m. NaF (as F) after 37 days, as compared to 495 c.c. per gram of volatile solids for the control (Figure 1). In Run V, with initial sludge samples of 700 ml., the corresponding values were 321 *vs.* 319 c.c. per gram of volatile solids after 40 days. Although a small amount of biocatalyst (approximately 430 p.p.m.) was added to both digesters on the fifth day of Run V, any real effect on the progress of digestion due to these enzymes and bacteria may be disregarded, as was concluded from the previously reported work (1).

The reaction velocity constants, k,

and the ultimate gas values, L, were not materially affected in the presence of the fluoride ion concentration. The actual values have been presented in Tables IV and V of the previous paper.

The specific gas yield in Run IV was greater for digester No. 12 as compared to digester No. 11, the control. The actual values were found to be 16.0 *vs.* 13.5 cu. ft. per pound of volatile matter destroyed, respectively. In Run V the yield was 15.3 *vs.* 13.8 cu. ft. per pound of volatile matter destroyed. The per cent volatile matter reduction in digesters No. 11 and 12 in Run IV showed 57 per cent reduction in the presence of the fluorides *vs.* 67 per cent reduction for the control. The corresponding reductions in Run V were found to be 33 per cent and 39 per cent, respectively.

The addition of almost 5 p.p.m. NaF as the fluoride ion, a concentration probably exceeding by at least 10 times the expected concentration, did not appear to affect those digestion activities studied in two experiments extending over 75 days. Although the

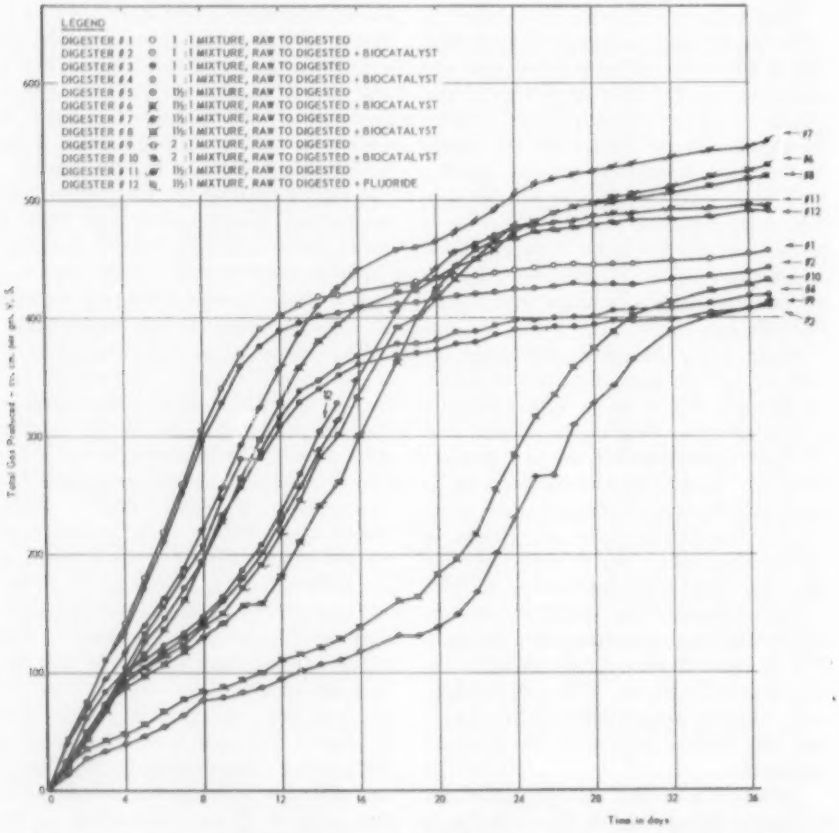

FIGURE 1.—Cumulative gas production, Run IV, showing effect of fluoride (digester No. 12) as against control (No. 11); conditions as given in reference (1).

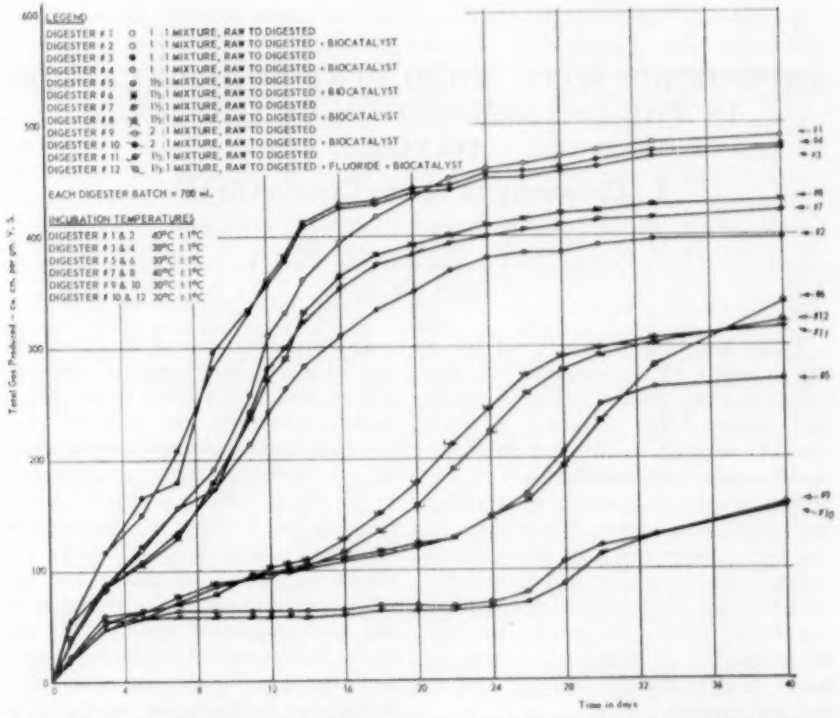
LEGEND
DIGESTER # 1 1 : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 2 1 : 1 MIXTURE, RAW TO DIGESTED + BIOCATALYST
DIGESTER # 3 1 : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 4 1 : 1 MIXTURE, RAW TO DIGESTED + BIOCATALYST
DIGESTER # 5 1½ : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 6 1½ : 1 MIXTURE, RAW TO DIGESTED + BIOCATALYST
DIGESTER # 7 1½ : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 8 1½ : 1 MIXTURE, RAW TO DIGESTED + BIOCATALYST
DIGESTER # 9 2 : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 10 2 : 1 MIXTURE, RAW TO DIGESTED + BIOCATALYST
DIGESTER # 11 1½ : 1 MIXTURE, RAW TO DIGESTED
DIGESTER # 12 1½ : 1 MIXTURE, RAW TO DIGESTED + FLUORIDE + BIOCATALYST
EACH DIGESTER BATCH = 700 ml.
INCUBATION TEMPERATURES
DIGESTER # 1 & 2 40°C ± 1°C
DIGESTER # 3 & 4 30°C ± 1°C
DIGESTER # 5 & 6 30°C ± 1°C
DIGESTER # 7 & 8 40°C ± 1°C
DIGESTER # 9 & 10 30°C ± 1°C
DIGESTER # 10 & 12 30°C ± 1°C
Total Gas Produced - cu. cm. per gm. V. S.
Time in days
#1
#4
#3
#8
#7
#2
#6
#12
#11
#5
#9
#10

FIGURE 2.—Cumulative gas production, Run V, showing effect of fluoride (digester No. 12) as against control (No. 11); conditions as given in reference (1).

data are too scant to draw any final conclusions, it appears unlikely from these results that the presence of a normal fluoride concentration would produce detrimental effects on the digestion of sewage solids.

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EXPERIENCE WITH SOLID PLATINUM ELECTRODES IN THE DETERMINATION OF DISSOLVED OXYGEN

I. University of North Carolina Studies

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There has long been a need for a rapid means of determining the dissolved oxygen concentration in water and sewage. The standard Winkler test (1) is most useful, but its many modifications are indicative of the extent to which the presence of interfering substances affects the results of the test. There are still many interfering substances for which suitable modifications of the Winkler test have not been found. In particular, the determination of dissolved oxygen in heavy sludges by the Winkler test is not satisfactory.

The need for improved methods of dissolved oxygen determination has resulted in development of the polarographic method using the dropping mercury electrode, which has received considerable study in recent years (2) (3) (4) (5) (6), and which is included in the Tenth Edition of "Standard Methods" (8). This method overcomes many of the difficulties with interferring substances in the Winkler test. The determination of dissolved oxygen in sludges and sludge-sewage mixtures by the polarographic method has many advantages over the Winkler method. Thus, the polarographic method seemed to offer strong possibilities for the determination of the change in dissolved oxygen, or oxygen utilization, in activated sludge-sewage mixtures in connection with research on the effect of oxygen tension on the biological treatment of sewage.

In determinations of dissolved oxygen in place, in "working" activated sludge-sewage mixtures, there may be interference with the mercury drop from the turbulence necessary to maintain the activated sludge in suspension in the liquor. There is also the serious problem of toxicity of the mercury when working with small samples. To circumvent these difficulties, use of a solid platinum electrode, of the rotating type, suggested itself. This electrode rotates at relatively high speed and should screen out any effect of the turbulence in the liquor necessary for maintaining sludge in suspension.

Ippen, Yoseph, and Posthill (5) were faced with a similar problem in determining dissolved oxygen in aerating liquors. They concluded that the rotating platinum electrode offered definite advantages over the dropping mercury electrode in that it could be placed directly in a stream of rising air bubbles and it would not be affected by turbulence.

This paper summarizes the results of an investigation into the use of the rotating platinum electrode for determination of dissolved oxygen in order to ascertain its practicability for use in research work on activated sludge-sewage mixtures.

Apparatus

The apparatus used was a modification of the Dorber Dissolved Oxygen Analyzer. A potential initiated from a dry cell is applied to a calomel reference electrode and rotating platinum

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electrode, which were inserted in a narrow-mouth sample bottle, or cell. Current flowing through the cell is a function of dissolved oxygen concentration and is measured on a microammeter. The platinum electrode is a 0.046-in. diameter platinum wire protruding 0.171 in. from the lower end of a brass shaft. The shaft is coated with 3 coats of Tygon paint to insulate it from the sample.

A 20,000-ohm voltmeter was placed in the circuit to measure applied voltage. A stroboscope was used to determine speed of rotation of the platinum electrode.

Supporting Electrolyte Required

It has been shown by Marsh (7) that a serious limitation of the rotating platinum electrode lies in the fact that it will work only in aqueous solutions having a conductivity of more than 0.01 reciprocal ohm per cm., which requires a concentration of about 1 per cent sodium chloride.

Samples of sewage and dilution water were used to determine the concentrations of salt required. All determinations were made with dissolved oxygen concentration constant at saturation with respect to air and room temperature. Chloroform was added to prevent utilization of the oxygen. Increasing increments of sodium chloride were added until the highest deflection was recorded by the microammeter. These data show an increased galvanometer deflection with increasing salt concentrations, up to 1.1 per cent. As excessive electrolyte concentration has no observable effect, it was decided to inoculate all subsequent samples with sodium chloride to a concentration of 1.1 per cent.

Calibration

Current-voltage curves were run in the range of 0.63 to 0.86 v. at D.O. concentrations ranging from 0 to 36 p.p.m. The current measured increases with increased dissolved oxygen concentration. However, unlike the usual current-voltage curve found with the dropping mercury electrode, in no instance was there obtained a flat curve

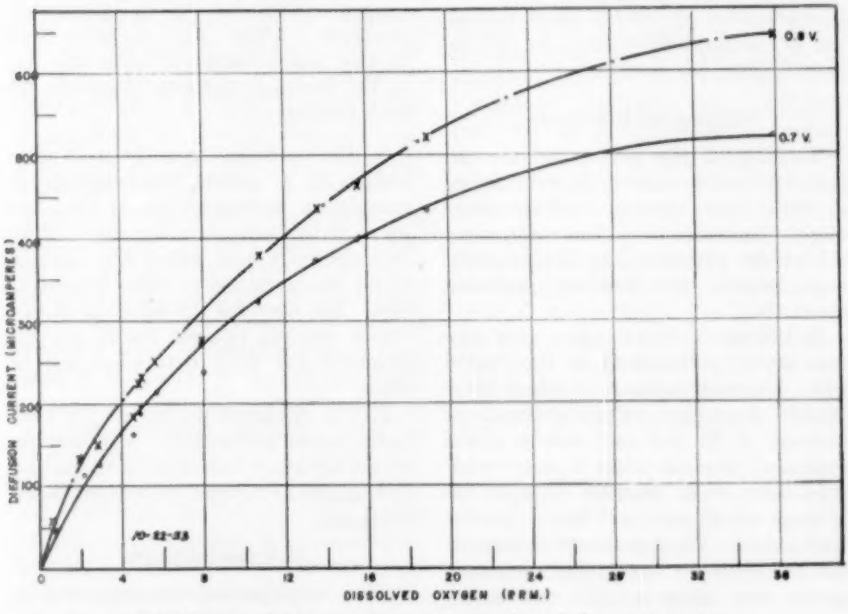

FIGURE 1.—Calibration curves for rotating platinum electrode.

where there is no increase in current with an increase in voltage. Failure of the curves to level off was also noted in the MIT studies (5), where current-voltage curves were run from 0 to 1.4 v.

Current and dissolved oxygen readings at 0.7 and 0.8 v. were taken from the current-voltage curves and plotted (Figure 1) to serve as calibration curves for this instrument. Theoretically, the diffusion current should be directly proportional to the dissolved oxygen concentration. However, the calibration curves are not linear.

Marsh (7) has shown that a linear function of dissolved oxygen and diffusion current can be obtained with pure sodium chloride brines at an applied potential of 0.73 v. and a dissolved oxygen range of 0 to 6 p.p.m. Beyond concentrations of 6.0 p.p.m. the calibration curve was found to be no longer linear. Ippen, Yoseph, and Posthill (5) obtained a calibration curve at 0.4 v. which was not linear. The calibration curve furnished by the Dorber Co. with their standard model is linear up to 10 p.p.m. The technique recommended by Dorber involves adding dry sodium chloride to the cell before adding the sample.

Filming of Electrode

Samples of tap water and sewage, inoculated with electrolyte, were placed in cells and current readings were made. Readings were then made every minute for periods up to 35 min. without cleaning the rotating platinum electrode.

A decrease in current flow with time was noted, particularly in the first 6 min. Current readings obtained after 10 min. for water samples dropped an average of 25 per cent below initial readings, whereas after 6 min. readings for sewage samples dropped an average of 43 per cent below the initial values. This apparent filming of the electrode in continuous measurements may cause erratic results, especially in sewage. It is believed that this is the reason for poor reproducibility.

Effect of Rotational Speed

Tests were made to determine how speed of rotation influences diffusion current measurements. With oxygen concentration in the sample equal to saturation at room temperature, the speed of rotation was varied between 300 and 860 r.p.m. Above 500 r.p.m., increasing the speed does not appear to have any effect on measured current, although, as the speed falls below 500 r.p.m., considerable reduction in current is noted. It would appear, therefore, that it is desirable to maintain the speed above 500 r.p.m., and that slight changes are of little significance.

Conclusions

The main object in consideration of the use of the rotating platinum electrode by the authors was its adoption for measurement of dissolved oxygen concentration in sewage and activated sludge and for the continuous measurement of D.O. in determining rates of oxygen utilization in sewage-sludge mixtures. There are, however, two factors which interfere with the use of the rotating platinum electrode for such studies:

1. The need for the addition of electrolyte is a serious disadvantage in continuous measurements of D.O., as the high salt concentration required by this electrode may affect the activity of the microorganisms under investigation. The need for the addition of salt would militate against use of the instrument for D.O. determinations in place.

2. The apparent filming of the electrode, noted particularly with sewage, would seriously interfere with its use in continuous oxygen utilization measurements.

Acknowledgment

This investigation was supported in part by a research grant from the Na-

tional Institutes of Health, U. S. Public Health Service.

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II. Georgia Institute of Technology Studies

By Robert S. Ingols

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The author has been extremely interested, as have been Lynn and Okun (see Part I, preceding), in a method for continuously recording the amount of dissolved oxygen in a sample of sewage during a B.O.D. test in order to get both the time of onset and the rate of the B.O.D. reaction. The dropping mercury electrode is accepted as a technique for determining dissolved oxygen (D.O.) for spot samples (1) or for the final D.O. in the B.O.D. test (2). However, the mercury itself is very toxic, and the addition of the liquid mercury over an extended time to a sample of sewage in a modified Sierp apparatus prevents the maintenance of a constant liquid volume, which is highly desirable in attempting to determine the volume of oxygen utilized. In a dilution B.O.D. test, the added liquid mercury makes the designing of equipment difficult because the technique requires the confinement of a liquid sample within a closed container.

Alternating Potential

A solid platinum electrode, therefore, would be highly desirable for following both the time of onset of the biochemical reaction and the rate of its procedure. In 1949, Olson, Brackett, and Crickart (3) published a technique which used a solid stationary platinum electrode and a calomel half-cell electrode as the electrode pair for the determination of D.O. in algae suspensions. The solid platinum electrode at low negative potentials of less than 1 v. tends to accumulate a film of hydrogen gas, which causes a decrease in current flow as it accumulates. The D.O. reacts at the platinum surface to remove the hydrogen film and permit a higher current flow than would occur in its absence, but there is still a steadily decreasing current flow caused by polarization of the electrode. In the method of Olson *et al* (3) the electrode was depolarized and the hydrogen film removed both by alternating the charge and by rest periods between each charge.

Thus, with a 10-sec. cycle, there were four periods of 2.5 sec.: during the first period, the platinum was negatively charged; during the second period, there was no charge; during the third period the platinum was positively charged; and during the fourth period, there was no charge. Because the D.O. can control the current flow only when the platinum is negative, the D.O. is measured only during a portion of the first period. During the first instant of negative charge on the platinum, there is a large surge of current flow. As the charge is continued, the quantity of current flow is much less because the electrode has become covered with a hydrogen gas film. The quantity of current flow at this time is a result of an equilibrium between the resistance to flow caused by the hydrogen gas film and the tendency to prevent the hydrogen gas film by the D.O. The final second of the 2.5 sec. is used for measuring the current flow to indicate the D.O. concentration.

The quantity of current flow is dependent on the surface area of the platinum at a constant D.O. It was found that a platinum electrode that gave 50μa. at saturation D.O. for air was convenient with the equipment built in the author's laboratory.

After a conference with Olson, an instrument was developed in the laboratory and was tested for several months in order to determine its suitability for the determination of D.O. during the B.O.D. reaction. It developed that the technique was highly reproducible, that the results were easily obtained with a sufficient degree of sensitivity to make them highly desirable for the B.O.D. reaction, and that no limit was found for the apparatus to give a straight-line curve between D.O. concentration and current flow. When, however, the electrode pair was immersed in sewage, the instrument worked normally for a few minutes but then no difference was found in the current flow between the oxygen-saturated sewage and the dissolved-oxygen-deficient sewage, because the current flow remained at the oxygen saturated value. This lack of difference in current flow with high and low D.O. values might be expected from the work by Lynn and Okun who show that there is a continually decreasing value for the current flow when the rotating platinum electrode was placed in sewage. However, in this case, the current flow failed to decrease in the absence of oxygen with alternating potential electrodes rather than the converse as with the rotating electrode. Thus, it appears that the platinum electrode became covered with a film which did not permit a decrease in current flow from an accumulation of hydrogen gas film on the platinum when the dissolved oxygen was driven out of solution. It was realized from these results that the technique for determining dissolved oxygen developed by Olson *et al* (3) was not applicable for use with sewage, despite the fact that it would work very well in comparatively pure water where only algae were present. In a private communication, Olson indicated that there had been some difficulties in using the technique for the determination of dissolved oxygen where the algae suspension had been homogenized; that is, where the cells had been broken down and the enzymes liberated into the medium.

Coatings Tried

Considerable time was spent attempting to find a film or coating which might be placed on the platinum electrode to keep away the film which would prevent the platinum from polarizing in the absence of oxygen. For this work the platinum electrode was covered with collodion from various ether-alcohol mixtures; the membrane adhered to the platinum surface very well at first, but when the covered electrode was immersed over a period of time, the collodion cover swelled and loosened from the platinum. The

collodion membrane was completely unsatisfactory within a few hours, even though it helped for a short time. Other water-insoluble membranes behaved similarly to that of the collodion, and this approach to the problem was soon abandoned. In an attempt to determine why the electrode system would not work in the presence of sewage, yet would work in pure water, some of the sewage was boiled and the oxygen changed mechanically by bubbling first oxygen and then nitrogen through the sample. When this technique was used, the oxygen depletion caused a reduction in the current flow, and the electrode system permitted the current flow to follow the dissolved-oxygen level very well. It was concluded, therefore, that enzymes in the sewage were responsible in part for a catalytic conversion of the hydrogen into hydrogen gas at a constant current density that did not permit a differentiation of the presence or absence of dissolved oxygen.

Tap Water Study

The rotating platinum electrode discussed by Lynn and Okun has also been studied by the author for the determination of dissolved oxygen in tap water. A platinum electrode rotating at 600 r.p.m. was immersed in a portion of tap water. It was found that the electrode was sensitive, but that the results were reproducible only to ± 10 per cent, even in clear water. Then it was found that the current density was markedly reduced by a floc of aluminum oxide which was caught on the platinum electrode as it rotated in the sample. The instrument and the study of the rotating platinum electrode was abandoned. It is realized that a redesign of the platinum wire, as it protrudes from the rotating shaft, might have aided in the reduction of the number of particles which would catch on the platinum, but only one particle was evident in the sample. It would seem, therefore, that this would not be a particularly desirable system for measuring dissolved oxygen in sewage or activated sludge, where it would be most helpful, because in activated sludge there would also be a large number of obvious flocs which could catch on any protrusion from the shaft of the rotating electrode.

Conclusions

It is concluded, therefore, that although several rather desirable techniques for determining dissolved oxygen have been reported in the literature, these are designed for specific applications. The use of a solid platinum electrode for determining dissolved oxygen continuously in sewage has not come to the attention of the author. The method of Olson, Brackett, and Crickart (3) has the simplest electrode system and the best reproducibility for the determination of dissolved oxygen in a sample which is comparatively free of biological degradation products. The rotating platinum electrode is desirable for the determination of dissolved oxygen in water free of flocs and highly saline, as pointed out by Lynn and Okun.

Acknowledgment

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INFLUENCE OF ANIONIC DETERGENTS ON THE DIFFUSED AIR ACTIVATED SLUDGE PROCESS

By P. N. Degens, Jr., H. van der Zee, and J. D. Kommer

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One of the most important conditions for satisfactory biological treatment of sewage is the proper functioning of the installation used; that is, the trickling filters or the activated sludge plant.

In this investigation into the influence of synthetic detergents on the biological step of sewage purification, the diffused air activated sludge process was studied because there is an installation of this type operating in West Amsterdam.

A pilot plant was built consisting of two uniform, continuously working units, the principal parts of which are an aeration tank, a Dortmund settling tank, and a re-aeration tank (Figure 1). Each unit is fed with settled sewage from the full-scale plant in West Amsterdam. This sewage is pumped into the 15-l. aeration tank, where it is mixed with approximately 20 per cent of activated sludge and aerated for about 3 hr.

At the end of this period the mixed liquor is transferred to the 8-l. settling tank through an overflow tube, the settled effluent being drained off and the activated sludge re-aerated in the 8-l. re-aeration tank for 8 to 10 hr. before it is recycled.

Unit I receives the sewage to which synthetic detergents have been added; unit II serves to carry out the blanks. Two types of syndets were used: a secondary alkyl sulfate (Teepol) and an alkylaryl sulfonate (a propylene tetramer benzene sulfonate). It may be observed that the settled sewage fed to the pilot plant already contained some syndets, both of the alkyl sulfate and of the alkylaryl sulfonate types, in average concentrations of 1 to 6 p.p.m.

I. EXPERIMENTS WITH SECONDARY ALKYL SULFATE

Conditions

For the experiments with secondary alkylsulfate (added as Teepol), the process conditions for each unit were as follows. The aeration tank influent (about one population equivalent) was maintained at a flow of 5 l. per hour, with return activated sludge feed (12 to 15 g. of dry matter per liter) of 1 l. per hour. Air dosage (about 1.8 cu. m. per person per day) amounted to 75 l. per hour, with the mixed liquor aeration being carried on for 3 hr. The settling tank detention period was 1.5 hr.; the re-aeration time was 8 hr. for an activated sludge feed of 1 l. per hour.

Process Control

As a means of checking the purification process, the following values were determined:

1. Oxygen content of mixed liquor (aeration tank).
2. Sludge index (settling tank).
3. 5-Day B.O.D. (effluent).
4. Oxygen consumed from $KMnO_4$ (effluent).
5. Nitrate content (effluent).
6. Alkyl sulfates and alkylaryl sulfonates (effluent). The analytical methods used for determining these values are given in Appendix I.

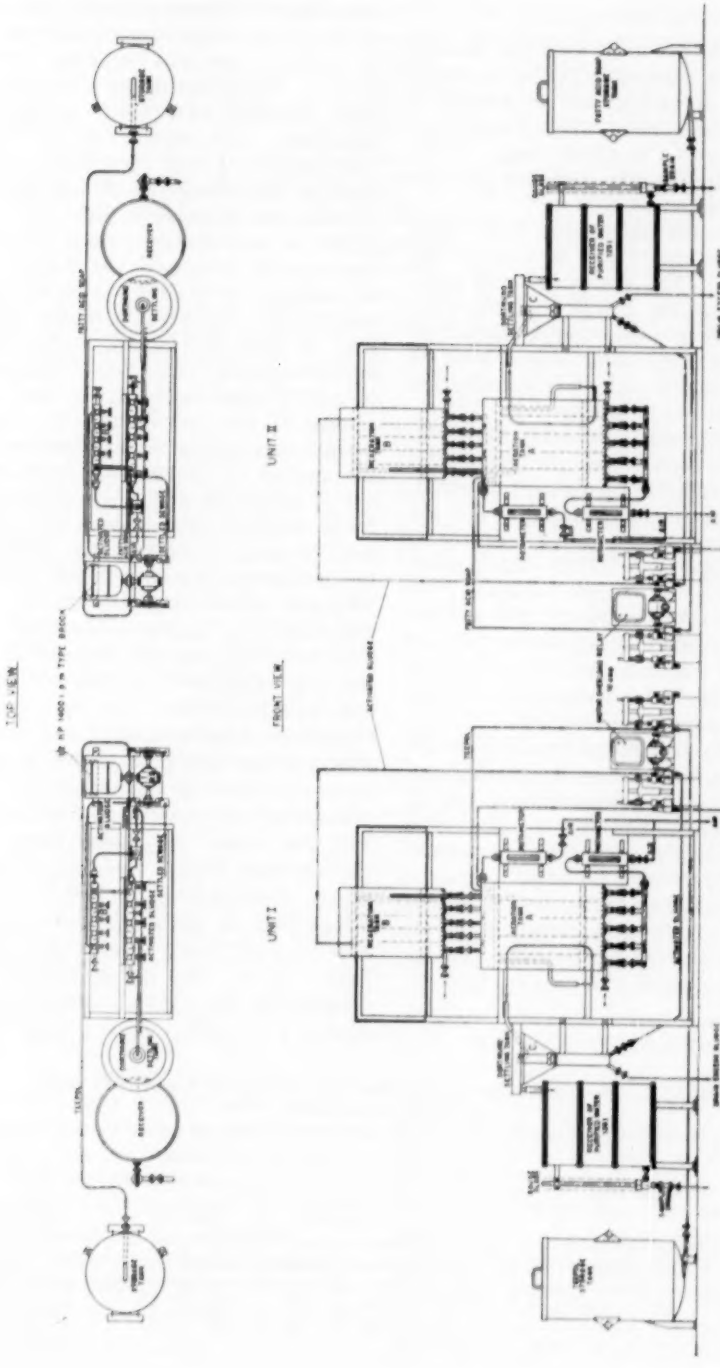

FIGURE 1.—Duplicate pilot plant for activated sludge treatment of waste water.

Results

First, the two units were put through a two-week running-in period to ensure identical operation, and to provide a reliable comparison when Teepol was added to unit I at a later stage. Table I gives the weekly averages for the running-in period.

The results show that both units work excellently and in exactly the same way. The sludge index is good, as are also the B.O.D. and the O.C. of the effluent; the oxygen content of the mixed liquor is on a good level (1 to 2 p.p.m. of O_2); and nitrification (NO_3 content) is satisfactory.

As a next step, secondary aklyl sulfate in the form of a dilute Teepol solution was added to the influent of unit I, the influent flow remaining at 5 l. per hour and consisting of 4.2 l. of settled sewage (average B.O.D. 325 p.p.m.) with 0.8 l. of Teepol solution (300 p.p.m. of active matter). The concentration of alkyl sulfate in the influent of unit I was therefore: 50 p.p.m. + x p.p.m. (the latter term represents the 2- to 5-p.p.m. concentration already present in the settled sewage), in addition to 3 to 7 p.p.m. of alkylaryl sulfonate. A concentration of 50 p.p.m. of alkyl sulfate * is higher than is ever likely to be reached in sewage, even in the distant future.

As the B.O.D. of the settled sewage —Teepol mixture is about 70 points higher than that of the settled sludge alone, the blank (influent of unit II) was adjusted correspondingly; that is, to 4.2 l. of settled sewage and 0.8 l. of sodium stearate solution (250 p.p.m.) The other process conditions were identical with those previously described. The results of the first (continuous) 4-week experiment and those of the second, which took about 6 weeks, are recorded in Table II.

One is immediately struck by the fact that in both runs the B.O.D. of the effluent of unit I (with Teepol added) was considerably higher than that of unit II (blank) during the first two weeks. The B.O.D. removal in unit I was about 88 per cent, as against 97 per cent in unit II. This implies that during the first two weeks the process of purification with the aid of activated sludge was inhibited by the presence of secondary alkyl sulfate, in spite of the fact that most of this compound was converted (about 55 p.p.m. of active matter in the influent and 5 to 7 p.p.m. in the effluent). This inhibition was also perceptible in the O.C. values and the NO_3 contents, and it is noteworthy that the oxygen content in aeration tank I was much lower during this period than it was in aeration tank II (blank).

Contrary to expectation, during the first two weeks the sludge index of the activated sludge from unit I was higher than that of unit II, which means that the activated sludge from unit I settled more readily than that from unit II. (By the method of determination used, a high sludge index indicates a sludge with a high dry

* All syndet concentrations are recorded in p.p.m. of active matter.

TABLE I.—Weekly Averages during Running-In Period for Experiments with Secondary Alkyl Sulfate

Running-In Period	Sludge Index		O_2 Content, Aeration Tank (p.p.m.)		Effluent					
					B.O.D. (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)	
	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II
1st week	149	144	1.1	1.2	12	14	19	19	9	9
2nd week	119	122	1.8	1.8	16	14	16	15	12	11

TABLE II.—Results of Experiment with 50 P.P.M. Secondary Alkyl Sulfate

Exper. Period[1]	Sludge Index		O_2 Content, Aeration Tank (p.p.m.)		Effluent									
					B.O.D. (p.p.m.)		O.C. (p.p.m.)		NO_2 (p.p.m.)		Sec. Alkyl Sulfate (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]
(*a*) First Run														
1st week	125	117	0.8	2.2	43	12	17	13	9	18	7	0	3	2
2nd week	135	95	1.3	2.8	36	10	17	15	7	9	6	0	3	2
3rd week	150	145	2.7	2.8	13	12	16	16	8	7	1	0	2	2
4th week	142	137	1.9	2.1	20	18	14	14	6	6	1	0	3	2
5th week	151	151	1.7	1.8	37	34	17	17	11	10	1	0	3	2
(*b*) Second Run[3]														
1st week	139	122	0.5	2.5	30	6	14	8	1	12	6	0	2	2
2nd week	114	103	1.4	2.2	34	7	14	11	6	9	5	0	2	2
3rd week	113	114	2.8	2.8	14	15	10	10	8	8	0	0	2	2
4th week	114	116	—	—	8	7	7	7	7	6	1	0	2	2
5th week	114	116	2.5	2.3	11	9	9	9	11	10	0	0	2	2
6th week	96	95	2.6	2.4	18	18	9	11	7	7	0	0	2	2

[1] After running-in time.
[2] Blank (control).
[3] With fresh activated sludge.

solids content matter in a small volume; in other words, a heavy, readily settling sludge.)

By the end of the second week the activated sludge in unit I had adapted itself to the high dosage of secondary alkyl sulfate and the purification of the sewage proceeded in exactly the same way as in the blank. This is evident from the B.O.D., O.C., and NO_2 contents of the unit I effluent, which were in both runs the same as those of the unit II (blank) effluent. The oxygen content in the unit I aeration tank was on the same level as that of the blank, as was also the sludge index. Moreover, the secondary alkyl sulfate was removed almost quantitatively from the influent, its content in the effluent being negligible.

No frothing was observed in the aeration tanks during either of the experiments, not even during the first two weeks.

Conclusion

In the diffused activated sludge process the purification of settled sewage with an abnormally high concentration (50 to 55 p.p.m. of active matter) of secondary alkyl sulfate (Teepol) is somewhat inhibited during an initial period of some two weeks. After the activated sludge has become adapted to this concentration of secondary alkyl sulfates, no influence whatever upon the treatment processes is observed. The B.O.D., O.C., and NO_2 contents of the effluent of the syndet experiments were the same as those of the effluents of the blanks, as were also the sludge index and oxygen content in the aeration tanks. The secondary alkyl sulfate was broken down almost quantitatively during the biological treatment process. No foaming was observed.

From the laboratory experiments by

TABLE III.—Weekly Averages during Running-In Period for Experiments with Alkylaryl Sulfonate

Running-In Period	Sludge Index		Effluent					
			B.O.D. (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)	
	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II
1st week	75	73	13	13	12	13	17	17
2nd week	82	84	14	13	12	12	5	6

Gaillard (1), Manganelli (3) and Rudolfs (4), as well as from the full-scale experiments by Hurley (2) (also with trickling filters), the conclusion may be drawn that alkyl sulfates up to 150 p.p.m. as sold (30 p.p.m. active matter) have no influence on the purification process and on the quality of the activated sludge and the final effluent.

II. EXPERIMENTS WITH ALKYLARYL SULFONATE

Normal Process Conditions and 30 P.P.M. Alkylaryl Sulfonate

Conditions

After the pilot plant has been thoroughly overhauled the two units were run in with settled sewage under the same conditions as mentioned in Section I, until the process results in the two units were identical (see Table III). An alkylaryl sulfonate (propylene tetramer benzene sulfonate) was then added to the influent of unit I in the form of a dilute solution of this syndet, the feed rate remaining 5 l. per hour, containing 4.2 l. of settled sewage (average B.O.D. 325 p.p.m.) and 0.8 l. of syndet solution with 155 p.p.m. of active matter. The concentration of alkylaryl sulfonates in the influent of unit I was therefore 25 p.p.m. + x p.p.m. (the latter term represents the 3- to 7-p.p.m. concentration already present in the settled sewage), in addition to 2 to 5 p.p.m. of alkyl sulfates.

As a solution of 28 to 32 p.p.m. of alkylaryl sulfonate has no B.O.D., the influent of unit II (blank) was accordingly adjusted to 4.2 l. of settled sewage plus 0.8 l. of tap water.

TABLE IV.—Results of Experiment with 30 P.P.M. Alkylaryl Sulfonate, Normal Process Conditions

Exper. Period[1]	O_2 Content, Aeration Tank (p.p.m.)		Effluent							
			B.O.D.[4] (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]
1st week	0	1.8	30	5	16	7	0	10	17	2
2nd week	0	2.3	35	7	15	8	0	4	21	1
3rd week	0	2.1	27	7	16	8	0	3	20	2
4th week	0	1.5	34	10	16	9	0	2	19	2

[1] After running-in time.
[2] Blank (control).
[4] Average influent B.O.D. = 275 p.p.m.

The other operational conditions in the two units were the same as those recorded in Section I.

Process Control

To enable close control of the process, almost the same tests were carried out as mentioned in Section I.

Results

Every day samples of the effluent and of the activated sludge of the two units were analyzed separately. The average values for each week (Tables IV and V) were calculated from the daily results.

From Table IV it may be inferred that a dosage of 25 p.p.m. of alkylaryl sulfonate during the entire 4-week period has a certain influence on the purification process. Whereas in the experiments with secondary alkyl sulfate (see Section I) the activated sludge adjusted itself after a given running-in time to the changed composition of the sewage, in this experiment with alkylaryl sulfonate (about 30 p.p.m.) this was not the case.

The effluent of unit I was turbid; the average B.O.D. removal was 88 per cent instead of the 98 per cent obtained in the blank. The O.C. value of the effluent of unit I was higher than that of the effluent of unit II. It is conspicuous that no nitrification occurred in unit I, and no free oxygen could be detected in the mixed liquor in the aeration tank. Moreover, there was sometimes a good deal of froth, mainly in the last section of the aeration tank of unit I. This only occurred on Sundays, during the night and early morning, during the periods when the settled sewage has the lowest concentration of suspended solids. In the blank unit (settled sewage with 2.5 p.p.m. of alkylaryl sulfonate and about an equal concentration of alkyl sulfates) there was never any frothing.

The effluent of unit I still contained a considerable portion of the alkylaryl sulfonates (about 20 p.p.m. of the original 30 p.p.m.), which was also the case in the effluent of the control unit (2 of the original 5 p.p.m.)

The color of the activated sludge in the settling tank of unit I was darker than that of the activated sludge of unit II. The sludge index of unit I (see Table V) was unexpectedly good and the relatively heavy sludge settled readily. The sludge contained much syndet, however, both alkyl sulfate and alkylaryl sulfonate.

Evidently during regeneration of the activated sludge these compounds are insufficiently broken down in unit I. Under the given experimental conditions the concentration of alkylaryl sulfonates in the circulating sludge rises to a level that is undesirable for the activity of the sludge, apparently reaching a given constant value (in unit I up to 1.67 per cent).

TABLE V.—Characteristics of Activated Sludge of Experiment with 30 P.P.M. Alkylaryl Sulfonate, Normal Process Conditions

Exper. Period[1]	Sludge Index		Alkyl Sulfate[3] (%)		Alkylaryl Sulfonate[3] (%)	
	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]
1st week	111	86	0.17	0.12	1.24	0.18
2nd week	121	76	0.28	0.12	1.59	0.20
3rd week	145	73	0.30	0.12	1.67	0.25
4th week	148	72	0.26	0.12	1.67	0.26

[1] After running-in time.

[2] Blank (control).

[3] In dry matter of activated sludge; dry solids averaged 12 g. per liter for unit II (control) and 15 g. per liter for unit I.

The extent of the biological conversion of the alkylaryl sulfonates can be seen by drawing up the following balance:

	Alk. Ar. Sulf. (mg./day)
Input:	
Influent, 24 hr. × 5 l./hr. × 30 p.p.m.	3,600
Discharge:	
Effluent, 24 hr. × 5 l./hr. × 20 p.p.m.	2,400
Excess act. sludge, 1 l./day	260
Total	2,660
Converted, biologically	940

From this balance it is evident that about one-quarter of the alkylaryl sulfonates in the influent was converted. The biological conversion of the alkyl sulfates was slightly inhibited by the presence of high concentrations of alkylaryl sulfonates. The effluent of unit I was not always free of alkyl sulfates, whereas it was in the previous experiment and in the controls. This phenomenon was accompanied by a higher concentration of alkyl sulfates in the activated sludge of unit I (after establishment of equilibrium; about 0.28 per cent on a dry basis compared with 0.12 per cent in the control (see Table V)).

In spite of the fact that there was also a certain content of syndets in the activated sludge of unit II (control)—specifically, 13 p.p.m. alkyl sul...s (= 0.12 per cent dry basis) and 25 p.p.m. alkylaryl sulfonates (= 0.25 per cent dry basis)—these concentrations in the sludge had no effect at all on its activity and, under the given conditions, the required degree of purity of the effluent was achieved.

Conclusion

From this series of experiments it can be concluded that the purification of settled sewage (B.O.D. 275 p.p.m.) with the aid of activated sludge is to some extent inhibited by the presence of 30 p.p.m. of alkylaryl sulfonate in the settled sewage. Settled sewage containing about 5 p.p.m. of alkylaryl sulfonate when purified has the very good B.O.D. of about 7 p.p.m., but the same settled sewage with 30 p.p.m. of alkylaryl sulfonate subjected to the same process is purified only to a B.O.D. of about 32 p.p.m., the target value being a B.O.D. of less than 20 p.p.m.

The activity of the activated sludge is affected by alkylaryl sulfonates (see also Gaillard (1), Manganelli (3) and Rudolfs (4)); that is, by an excessively high concentration of this compound in the sludge and also as a result of too low an oxygen content of the mixed liquor in the aeration tank, due to inadequate oxygen consumption in this medium (see also Manganelli (3)).

For the sewage plant manager it is important to know the maximum permissible concentration of alkylaryl sulfonate in settled sewage (between 5 and 30 p.p.m.) that does not cause any inhibition of the purification process under normal conditions. He will also have to ascertain whether process conditions can be modified so as to ensure that the sewage is sufficiently purified if, under normal conditions, the maximum permissible concentration of alkylaryl sulfonates is exceeded.

In the investigation described hereinafter both these aspects of the problem are dealt with, starting with the determination of the maximum permissible alkylaryl sulfonate concentration in the settled sewage when the process is run under normal conditions.

Re-Activation of Sludge

Before experimenting with a lower dosage of alkylaryl sulfonates it was ascertained whether the sludge that had lost some of its activity in unit I during the previous experiment might not be re-activated to the level of that of the control. The addition of alkylaryl sulfonate to unit I was therefore discontinued, the unit being fed with the same type of sewage as unit II; that is, with 4.2 l. of settled sewage (con-

taining about 5 p.p.m. both of alkyl sulfate and alkylaryl sulfonate detergents) and 0.8 l. of tap water per hour, both units running under the same normal process conditions as in Section I.

The results (Table VI) show that the sludge index of unit I decreased, in other words, the sludge settled more slowly. At the end of about 20 days its color was about the same as that of the control.

The content of alkylaryl sulfonate, both in the activated sludge and in the effluent of unit I, decreased rapidly, on the one hand through biological conversion, on the other through being passed off via the effluent and the superfluous sludge (accretion). At a concentration of about 0.40 per cent of alkylaryl sulfonate in the dry matter of the activated sludge this sludge is again sufficiently active to effect the required purification of the sewage under normal conditions. At this value both the B.O.D. and the O.C. value of the unit I effluent satisfied the specifications; also, this effluent was no longer turbid.

When determining the oxygen content of the mixed liquor in the aeration tank of unit I, it was found that in about 20 days the liquor again contained free oxygen.

From this experiment it may, to some extent, be concluded that the concentration of alkylaryl sulfonate in the activated sludge must not exceed a given maximum under certain process conditions. With a high alkylaryl sulfonate content in the settled sewage, this maximum, which under normal process conditions will be in the neighborhood of 0.40 per cent (as referred to dry matter), will be easily exceeded, because this type of detergent is very slow to break down biologically. Possibly its decomposition can be promoted by maintaining a sufficiently high oxygen concentration in the aeration tank.

To determine the permissible concentration of alkylaryl sulfonates in the settled sewage, so as to obtain an effluent up to standard, an experiment was carried out with 12.5 p.p.m. of alkylaryl sulfonate in the influent of unit I of the pilot plant.

Normal Process Conditions and 12.5 P.P.M. Alkylaryl Sulfonate

After the pilot plant had been cleaned and filled with fresh activated sludge the two units were run in for some time applying the same normal conditions as previously described. Alkylaryl sulfonate was then added to the influent of unit I, the total content of this compound being 12.5 p.p.m.

TABLE VI.—Re-Activation of Sludge after Discontinuing Addition of Alkylaryl Sulfonates

Days[1]	Sludge Index		Alkylaryl Sulfonate[2] (%)		Effluent					
					B.O.D. (p.p.m.)		O.C. (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II	Unit I	Unit II
0	168	82	1.66	0.25	33	12	19	10	14	2
5	161	60	1.30	0.25	24	5	15	8	6	1
10	163	78	0.90	0.22	21	8	17	11	3	2
15	163	89	0.53	0.25	17	9	16	9	2	2
20	—	—	0.39	0.27	13	14	15	10	2	2
25	138	106	0.41	0.25	12	14	14	15	2	2

[1] From start of experiment.

[2] In dry matter of activated sludge; dry solids averaged 13 g. per liter for unit II (control) and 15 g. per liter for unit I.

TABLE VII.—Results of Experiment with 12.5 P.P.M. Alkylaryl Sulfonate, Normal Process Conditions

Exper. Period[1]	B.O.D.[2] (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]
1st week	40	22	20	16	0	0	7	3
2nd week	31	12	19	15	0	0	6	2
3rd week	37	13	19	13	0	0	5	2
4th week	32	12	19	15	0	0	5	2

[1] After running-in period.
[2] Average influent B.O.D. = 275 p.p.m.
[3] Blank (control).

(about 5 p.p.m. already in the settled sewage plus the 7.5 p.p.m. added).

Results

The average weekly results of this experiment (Tables VII and VIII) reveal that the effluent of unit I was not yet up to standard in comparison with the control (unit II). The B.O.D. was still too high (averaging 33 instead of 12 p.p.m. as in the control); yet, a B.O.D. removal of $275-33/2.75 = 88$ per cent was achieved, as compared with 96 per cent in the blank. No free oxygen was detected in the mixed liquor in the unit I aeration tank. In this experiment no nitrification was observed, either in unit I or in unit II. It is notable that the sludge index, too, was still higher than that of the blank; contrary to expectation, unit I still had a heavier activated sludge, which settled more readily. There was no frothing at all in the blank (unit II). Occasionally there was some frothing in unit I, usually on Sundays, during the night or early morning, when the settled sewage was less concentrated than in the daytime.

To ascertain the maximum permissible concentration of alkylaryl sulfonate in the settled sewage at which a well-purified effluent is obtained under normal process conditions, one may perhaps utilize the relation existing, up to a point, between the percentage of alkylaryl sulfonate in the activated sludge (as referred to dry matter) and its concentration in the settled sewage (Figure 2). In interpreting this curve it must be borne in mind that the content of alkylaryl sulfonate in the settled sewage of the blanks (unit II) varied between 3 and 7 p.p.m. (although an average of 5 p.p.m. was assumed in all the tests), and in conse-

TABLE VIII.—Characteristics of Activated Sludge of Experiment with 12.5 P.P.M. Alkylaryl Sulfonate

Exper. Period[1]	Sludge Index		Alkyl Sulfate[4] (%)		Alkylaryl Sulfonate[4] (%)	
	Unit I	Unit II[2]	Unit I	Unit II[2]	Unit I	Unit II[2]
1st week	152	126	0.20	0.10	0.60	0.26
2nd week	156	119	0.22	0.11	0.58	0.26
3rd week	158	125	0.19	0.08	0.51	0.22
4th week	191	134	0.21	0.12	0.47	0.18

[1] After running-in period.
[2] Blank (control).
[4] In dry matter of activated sludge, which averaged 17 g. per liter for each unit.

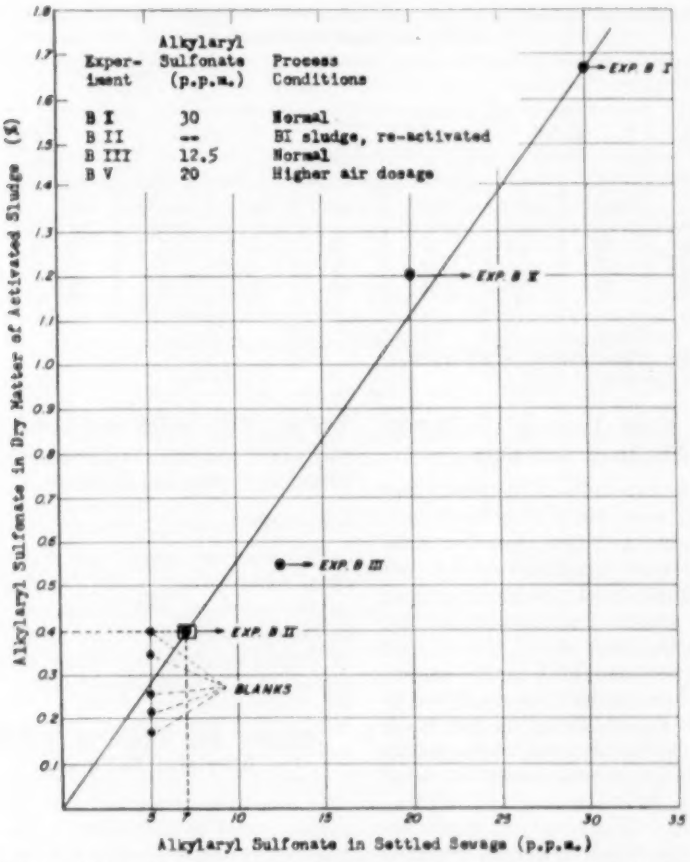

FIGURE 2.—Adsorption of alkylaryl sulfonate to activated sludge; pilot plant air dosage, 75 l. per hour.

quence in unit I it varied from 10 to 15 p.p.m. (this experiment) to 18 to 22 p.p.m. (the immediately following experiment) and 28 to 32 p.p.m. (the first experiment in this section). From the immediately foregoing experiment it might be deduced that for the pilot-plant experiments, with a normal air dosage of 75 l. per hour, the critical content of alkylaryl sulfonate in the dry activated sludge is 0.4 per cent (Table VI). According to Figure 2 this would correspond to about 7 p.p.m. of alkylaryl sulfonate in the settled sewage.

At the present consumption of syndets, this concentration will easily be exceeded in domestic sewage, so that it should be ascertained whether an improvement in the sewage treatment by the diffused air activated sludge process can be effected by modifying the process conditions.

To this end, in the first place the load of the aeration tank was reduced by 25 per cent, which prolonged the oxidation reaction time (see next section). Subsequently, under normal load the air dosage was increased by a factor of 3 (see second section following).

TABLE IX.—Results of Experiment with 30 P.P.M. Alkylaryl Sulfonate and 25 Per Cent Load Reduction

Exper. Period[1]	Effluent							
	B.O.D.[2] (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]
1st week	42	14	17	9	1	5	18	2
2nd week	37	14	18	9	0	1	14	2
3rd week	33	11	21	10	0	0	15	2

[1] After running-in period.
[2] Average influent B.O.D. = 275 p.p.m.
[3] Blank (control).

Reduced Plant Loading, 30 P.P.M. Alkylaryl Sulfonate

After the two units of the pilot plant had again been filled with fresh activated sludge and had run for some time at a water feed rate of 4 l. per hour (instead of 5 l. per hour) and an activated sludge feed rate of 0.75 l. per hour (instead of 1 l. per hour), the other experimental conditions remaining the same as those described in Section I, an additional 25 p.p.m. of alkylaryl sulfonate was continuously fed to unit I (total concentration about 30 p.p.m.) It was ascertained whether the increase in the mixed liquor-air reaction time thus obtained resulted in an improvement of the B.O.D. and O.C. removal.

Comparison of the results of this experiment (Tables IX and X) with those of Tables IV and V and Tables VII and VIII, which were both carried out under normal conditions, does not reveal any essential differences.

Conclusion

Reducing the plant load by 25 per cent, which prolongs the reaction time in the aeration tank, does not result in an improvement of the purification of settled sewage containing about 30 p.p.m. of alkylaryl sulfonates.

Higher Air Input, 20 P.P.M. Alkylaryl Sulfonate

It has been remarked that no free oxygen could be identified in the aeration tank of unit I when the alkylaryl sulfonate content was high (12.5 and 30 p.p.m., respectively), because apparently the oxygen absorption in this medium is inhibited. It was ascertained, therefore, whether an increase

TABLE X.—Characteristics of Activated Sludge of Experiment with 30 P.P.M. Alkylaryl Sulfonate and 25 Per Cent Load Reduction

Exper. Period[1]	Sludge Index		Alkyl Sulfate[4] (%)		Alkylaryl Sulfonate[4] (%)	
	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]
1st week	159	77	0.38	0.10	1.83	0.25
2nd week	169	81	0.30	0.05	1.71	0.24
3rd week	168	87	0.27	0.07	1.66	0.25

[1] After running-in period.
[3] Blank (control).
[4] In dry matter of activated sludge, which averaged 12 g. per liter for unit II and 15 g. per liter for unit I.

TABLE XI.—Results of Experiment with 20 P.P.M. Alkylaryl Sulfonate and Increased Air

Exper. Period[1]	O_2 Content, Aeration Tank (p.p.m.)		Effluent							
			B.O.D. (p.p.m.)		O.C. (p.p.m.)		NO_3 (p.p.m.)		Alkylaryl Sulfonate (p.p.m.)	
	Unit I[2]	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]
1st week	3.5	2.4	9	6	13	15	6	4	7.7	2.7
2nd week	3.2	1.9	11	7	15	14	10	4	10.0	2.6
3rd week	4.1	1.1	14	13	14	14	5	4	9.2	2.8
4th week	3.3	1.4	11	7	17	15	10	5	8.2	1.8
AFTER RETURNING UNIT I TO 75 L. OF AIR PER HOUR										
5th week	—	—	—	—	—	—	—	—	—	—
6th week	0.6	3.0	29	11	16	11	3	6	11.4	2.3
7th week	0.2	1.8	38	6	20	12	0	8	12.6	1.9

[1] After running-in period.
[2] 225 l. air per hour.
[3] Blank (control); 75 l. air per hour.

of the air dosage would improve the activity of the sludge.

After the pilot plant had been cleaned and filled with fresh activated sludge and the units allowed to run in so as to obtain identical operation under the conditions mentioned in Section I, the air dosage of unit I was increased to 225 l. per hour instead of the 75 l. per hour maintained in unit II. To the settled sewage of unit I alkylaryl sulfonate was added until the influent concentration was 20 p.p.m. By addition of tap water to the settled sewage of unit II the B.O.D. of the two units was brought to the same level, averaging 275 p.p.m. The other process conditions were the same as described in the first experiment under this section.

TABLE XII.—Characteristics of Activated Sludge of Experiment with 20 P.P.M. Alkylaryl Sulfonate and Increased Air

Exper. Period[1]	Sludge Index		Alkyl Sulfate[4] (%)		Alkylaryl Sulfonate[4] (%)	
	Unit I[2]	Unit II[3]	Unit I	Unit II[3]	Unit I	Unit II[3]
1st week	110	100	0.25	0.21	0.77	0.35
2nd week	142	105	0.24	0.21	1.09	0.35
3rd week	146	90	0.17	0.17	1.36	0.41
4th week	120	73	0.36	0.33	1.09	0.30
AFTER RETURNING UNIT I TO 75 L. OF AIR PER HOUR						
5th week	—	—	—	—	—	—
6th week	105	56	—	—	1.20	0.30
7th week	110	61	—	—	1.22	0.35

[1] After running-in period.
[2] 225 l. of air per hour.
[3] Blank (control); 75 l. of air per hour.
[4] In dry matter of activated sludge, which averaged 10 g. per liter for unit II and 13 g. per liter for unit I.

Results

From the average weekly results of this experiment (Tables XI and XII), the following observations may be made.

At an oxygen concentration of 3.5 p.p.m. in the aeration tank of unit I (containing activated sludge and a settled sewage with 20 p.p.m. of alkylaryl sulfonate), the B.O.D. of the sewage is reduced to below 20 p.p.m. and is therefore up to standard. Nevertheless, the average B.O.D. of 11 p.p.m. in the effluent of unit I is a little higher than that of the control (8 p.p.m.), in spite of the fact that the control unit received only 75 p.p.m. of air per hour.

The O.C. values of the effluents of the two units are equal. Owing to the higher oxygen dosage in unit I, the nitrification in this unit is higher than that of unit II.

Notwithstanding the higher oxygen concentration in the unit I aeration tank, the biological conversion of the alkylaryl sulfonate does not proceed more rapidly; about one-half the amount of the syndets originally present is still found in the effluent.

The sludge index of unit I is slightly better than that of unit II, but it is much more remarkable that in spite of the fact that the dry activated sludge of unit I contains about 1 per cent of alkylaryl sulfonate, this sludge remains sufficiently active under the given process conditions to effect adequate purification of the settled sewage.

Although in this experiment more air was passed in per unit of time than in the previous ones, no greater frothing was caused. Occasionally some froth was formed in the early hours of the morning and sometimes on Sundays.

Conclusions

By increasing the oxygen content of the mixed liquor in the aeration tank (in this investigation up to 3.5 p.p.m. of oxygen) it proved possible to purify settled sewage (B.O.D. 275 p.p.m.) containing alkylaryl sulfonate at the rate of 20 p.p.m. of active matter, in such a manner that the effluent was up to standard. Allowance will, however, have to be made for the fact that the effluent will invariably contain some alkylaryl sulfonate.

It is up to the sewage plant manager to ascertain what the minimum oxygen content in the aeration tank of his activated sludge plant must be to ensure good purification of the sewage. This will differ from plant to plant and for each type of sewage. The way in which the air is applied in the activated sludge process—that is, whether the diffused air system is applied, or Kessener brushes are used, or the Haworth bioaeration system (with paddles)—will also have some influence.

After-Treatment by Trickling Filter

Instead of purifying settled sewage by an activated sludge process, in practice trickling filters are often used, these being less sensitive to fluctuations in the composition of the sewage. If it is not possible for some reason to adjust the process conditions of an activated sludge plant so as to obtain

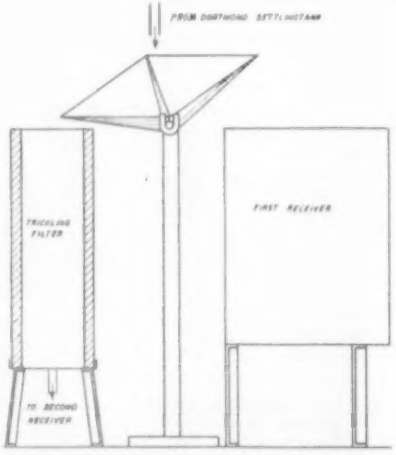

FIGURE 3.—Tipping bucket proportioning apparatus for trickling filter experiments.

TABLE XIII.—Results[1] of Trickling Filter Experiment

Exper. Period[2]	Trickling Filter Influent[3]				Trickling Filter Effluent			
	B.O.D. (p.p.m.)	O.C. (p.p.m.)	NO_3 (p.p.m.)	Alkylaryl Sulfonate (p.p.m.)	B.O.D. (p.p.m.)	O.C. (p.p.m.)	NO_3 (p.p.m.)	Alkylaryl Sulfonate (p.p.m.)
1st week	29	16	2	11.4	6	10	61	10.2
2nd week	38	20	0	12.6	9	11	74	10.5

[1] Weekly averages.
[2] After running-in period.
[3] Effluent of pilot unit I.

properly purified sewage, it would be possible to give it after-treatment in trickling filters.

Therefore, an experiment was carried out running the activated sludge pilot plant under normal conditions (continuation of the experiment with reduced plant loading and 30 p.p.m. sulfonate, but with 75 l. of air per hour and 20 p.p.m. of alkylaryl sulfonate in the unit I influent) and then passing the unit I effluent on to a trickling filter. This was to determine if the effluent, which still contained about 10 p.p.m. of alkylaryl sulfonate, could be purified up to standard through the trickling filter.

The test filter (Figure 3) consisted of a brick tube (inside diameter 10 cm., length 120 cm.) filled with stones from a full-scale trickling filter in operation, to accelerate bacterial maturing in the test filter.

The effluent of unit I of the activated sludge pilot plant was passed alternately to the trickling filter and to a collecting tank. This enabled a check to be kept on the influent and the effluent of the trickling filter, which received 2.5 l. of water per hour. Hence, the surface loading of the trickling filter was 305 l. per square meter per hour and the volume loading was 266 l. per cubic meter per hour.

The trickling filter was allowed to run in for about two weeks so as to make sure that the process of bacterial maturing was in equilibrium with the sewage to be purified. After this period the effect of the filter on the purification of the effluent of unit I of the activated sludge pilot plant was checked. The results (Table XIII) show that even when the sewage is passed rapidly through the filter the required reduction of the B.O.D. and O.C. of the effluent of unit I is obtained. Strong nitrification is effected, but there is hardly any biological conversion of alkylaryl sulfonate under these conditions.

Conclusion

Sewage containing alkylaryl sulfonates that has not been sufficiently purified by activated sludge can be brought up to standard as regards B.O.D. and O.C. by after-treatment in a trickling filter. The alkylaryl sulfonate is then only partially broken down, however, so that this type of compound will remain in the effluent.

III. GENERAL CONCLUSIONS

The experiments reported herein showed the following:

1. Secondary alkyl sulfate (as Teepol) in a concentration of 50 p.p.m. active material (= 250 p.p.m. as sold) in the settled sewage has no influence on the biological purification of this sewage after the activated sludge has adapted itself to this high syndet concentration, which concentration will never occur in actual practice. The alkyl sulfate is decomposed practically

quantitatively during the process and consequently hardly occurs in the effluent.

2. Under the same conditions as in the previous experiment, alkylaryl sulfonate (as a propylene tetramer benzene sulfonate) in concentrations of 30 p.p.m. and 12.5 p.p.m. active matter has an inhibitive influence on the purification of the settled sewage; not so at 5 p.p.m., however.

The activity of the activated sludge is influenced by alkylaryl sulfonate; specifically, by a high concentration of the sulfonate in the sludge and also by the oxygen content in the mixed liquor in the aeration tank being too low, which is caused by unsatisfactory oxygen absorption in this medium.

A reduction of the plant load by 25 per cent, which prolongs the reaction time in the aeration tank, did not result in an improvement in B.O.D. and O.C. removal of settled sewage (B.O.D. 275 p.p.m.) with 30 p.p.m. alkylaryl sulfonate (active matter).

By increasing the oxygen concentration in the mixed liquor in the aeration tank (in this investigation up to 3.5 p.p.m. O_2 by applying a three-fold increase of the air dosage) it was possible to purify settled sewage with an alkylaryl sulfonate content of 20 p.p.m. active matter to such an extent that an effluent meeting the B.O.D. and O.C. standard was obtained.

The same result was obtained by after-purification of the effluent from the activated sludge pilot plant, which had been given a "normal" air dosage, over a trickling filter.

As the biological conversion of alkylaryl sulfonates proceeds only slowly, it should be taken into account that a considerable part of this type of syndet will remain in the effluent.

Acknowledgment

The authors wish to thank the management of the N. V. Bataafsche Petroleum Maatschappij, the Hague, and the management of the Amsterdam Public Works for their permission to publish this paper.

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APPENDIX I.—ANALYTICAL METHODS USED FOR EXAMINATION OF EFFLUENT AND ACTIVATED SLUDGE

1. Sludge Index

The sludge index is a/b, where a is the p.p.m. of suspended solids, and b is the amount of sludge in per cent by volume, after 1-hr. settling of the mixed liquor. A quantity of 250 ml. of a homogeneous mixed liquor from the aeration tank was run into a 250-ml. graduated cylinder. After settling for 1 hr. the sludge volume was read

off. The suspended solids concentration (p.p.m.) of this mixed liquor was determined by filtering off and drying at 105° C.

2. Oxygen Content of Activated Sludge Mixture

The oxygen content of the mixed liquor in the aeration tank was determined according to the method of Seaman and Allen (5). To prevent oxygen consumption by the activated sludge during storage of the sample, about 2 g. of phenol per 100 ml. of sample was added in the sample bottle beforehand.

3. Oxygen Consumed (O.C.)

The oxygen consumed determination was carried out as described in: "Standard Methods" (6), p. 122. Instead of for 30 min., the sample was heated with $KMnO_4$ in a water bath for only 10 min., as is usual in the sewage plants in Amsterdam.

4. Biochemical Oxygen Demand (B.O.D.)

The 5-day B.O.D. was determined as described in "Standard Methods" (6), pp. 139–43.

5. NO_3 Content

The NO_3 content of the effluent was determined according to the colorimetric brucine method described by Dickinson (7).

6. Synthetic Detergents Content of Effluent

The content of alkyl sulfate and alkylaryl sulfonate in the effluent was determined according to the colorimetric methylene-blue method described by Degens *et al.* (8).

7. Synthetic Detergents Content of Activated Sludge

To determine the content of anionic detergents adsorbed on activated sludge, this sludge is extracted with a NaOH solution according to the following procedure.

Pipette 25 ml. activated sludge into a 300-ml. Erlenmeyer flask. Add 3 ml. NaOH 1:1. Place a reflux condenser on the Erlenmeyer flask and boil gently for 30 min. Allow to cool, transfer the liquid to a centrifuge tube, and centrifuge for 5 min. in an electric laboratory centrifuge. Pour the clear solution into a 250-ml. measuring flask and transfer the sludge residue to the Erlenmeyer flask with the aid of 30 ml. NaOH 2N. Boil again gently under the reflux condenser for 30 min., allow to cool, and transfer the liquid to a centrifuge tube. Centrifuge again for about 5 min. and transfer the clear solution to the previously mentioned measuring flask. Swirl up the sludge residue in the centrifuge tube with 30 ml. distilled water and centrifuge for 5 min. Pour the clear wash liquor in the measuring flask. Add a few drops of phenolphthalein and neutralize with 25 per cent H_2SO_4. Fill up the measuring flask to the mark with distilled water.

Determine the content of anionic detergents ($= a$ p.p.m.) of 10 ml. of this solution by the methylene-blue method (8). The total detergent content in the activated sludge is 10 a p.p.m.

As the dry matter content (dry solids concentration) of the activated sludge may vary, it is recommended that the syndet content be stated as a percentage of the dry matter of the sludge; therefore, the dry solids concentration of the activated sludge also must be determined.

EVALUATION OF TOXICITY

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First, it would seem wise to delimit the problem for this discussion. Disinfection is frequently accomplished by chemical agents; but this paper discusses chemical agents and their capacity for toxicity or stasis. It should be realized that there is no sharp break between the action of disinfection, stasis, and toxicity, and Porter (13) is very positive in his statement to that effect. Disinfection may involve a more rapidly developed irreversible reaction, whereas by definition the change which brings about stasis can be reversed. But all contact times and chemical concentrations are relative and their effects can be changed by other conditions.

It is the primary purpose of this paper not to discuss disinfection, but to discuss those conditions where the concentrations of chemical agents, primarily metallic ions, are in that range permitting metabolic activity at a reduced rate in relation to a control. The discussion is particularly pertinent to the addition of the toxic agents to waste treatment processes and stream sanitation.

In contrast to the discussion on waste treatment processes, higher organisms such as fish have a very limited range within which their metabolic activity can be varied. Thus, it is expected that it should be possible to determine an L_{D50} within rather narrow limits for many animals, and this is considered briefly in the latter part of the paper.

Several excellent literature reviews on toxicity have been published recently by subcommittees (2) (16) of the Research Committee of the Federation. It is the purpose of this paper to present concepts that may aid waste treatment engineers both in understanding the tremendous diversity in published toxicity values and also in thinking about a particular toxic waste problem.

Normal Cellular Activities

In order to understand or evaluate toxicity properly, it would seem advisable at the outset to review some of the normal functions of the bacterial cell being dealt with. The normal cell must take in food, oxidize some of this food for energy, synthesize some of the food into new cellular material, then discard the waste products of metabolism, finally divide into two daughter cells and then repeat the process. The first step in the activity or metabolism is, therefore, the movement or transportation of food and minerals from the outside of the cell to the interior of the cell where most of the actual metabolic processes take place. The nature of the cell membrane is not altogether known, but it is realized to be a combination of proteins and fats. Thus, it is semipermeable so that material in true solution and some lipoid substances or true fats can be transported across the membrane to the interior of the cell. Under optimum conditions of food concentrations and other environmental factors, it is well recognized that many bacteria can reproduce at least once every half hour, and that this rate of metabolism can continue for short periods of time. If one takes sugar as a representative food for metabolic processes, it is well accepted that approximately one-half of

the food taken in is used for the production of energy under aerobic conditions while approximately one-half can be used for the synthesis of new protoplasm. As far as is known, toxicity may manifest itself at any one of the various points in the normal metabolic process.

Toxicity *vs.* Disinfection

What is the generally accepted difference between disinfection and toxicity? Toxicity is generally associated with a reaction or reactions which may deter the metabolic processes in a cell, while not completely blocking them; on the other hand a disinfectant or lethal substance is expected to bring about complete or irreversible changes in the cell. In this category of lethal substances, it is common to place heat and such chemicals as chlorine; it is common to place in the toxic category such substances as mercury, chromium, lead, and silver, which generally (although capable of killing bacteria) are much slower to kill with a given concentration than chlorine. Thus, after a cell has been in contact with mercury for several hours, it is possible to remove the mercury so that the metabolism of the cell can return again to the normal pattern. There is, however, some evidence (6) to indicate that a reversal of some factor in heat and chlorine treated bacteria can occur.

Current Concepts of Toxicity

Various workers have developed different ideas as to how destructive forces interfere with or change the normal cellular physiology. Seifritz (19), by observing the naked protoplasm of the *Myxomycetae*, shows that toxicity is correlated with degree of rigidity of the protoplasmic gel, but it is not quite clear whether gelation is a symptom or a cause of the toxic mechanism. Robinson (15) emphasizes the importance of the cell membrane (interface of protoplasm and environment) in maintaining a higher salt concentration within the cell than is usually present in its environment; toxic substances interfere with the mechanism of actively removing water from within the cell and, thus, the assimilation of food. Green (5) realizes the importance of specific enzymes in understanding disinfection by chlorine; but the question arises whether the sulfhydryl of aldoase will be as vulnerable and specific to the mercuric ion as it is to chlorine.

Actually these concepts are not necessarily exclusive, but may indicate different approaches to the same problem. Seifritz (19) used a microscope and observed changes in the rate of flow in a protoplasmic mass and was particularly interested in the effect of anaesthetics. Other observations by Seifritz (20) have yielded lists of cations which indicate their relative toxicity. His explanations of the relative toxicity through ion hydration and valence have been questioned by Shaw (21) and Hurd-Karrar (7). Shaw believes that the relative degree of lethality of the toxic cations can be explained by the solubility product of the cation with sulfhydryl radicals of the protoplasm plus the state of well-being of the organism. Hurd-Karrar emphasizes that some of the ions behave as antimetabolites and that ion hydration and valence would have little bearing in explaining their relative toxicity to other toxic ions.

By studying the concept of active water transport as reviewed by Robinson (15) one can see the cell through the over-all chemical changes on the outside of the cell. It would seem that it provides an indication, without defining the cause or effect, of the observed changes in the physical character of the protoplasm described by Seifritz (19). It appears easier to study the concept of the factors controlling active water transport rather than direct microscopic observation of the physiological state; and certainly

for bacterial cells no direct microscopic observations of the protoplasm are yet possible.

The information which shows exact enzyme damage, resulting from a particular toxic substance, does not describe the general changes taking place as the result of the loss of the enzyme function. Thus, it might be said that mercuric chloride brings about a loss in the production of energy by blocking aldoase and that the loss of energy results in an eventual loss of the proper internal salt concentration, which may in turn control gelation.

Hurd-Karrer (7) indicates that the toxicity of some substances is caused by the inability of a test wheat plant to differentiate between a necessary ion and its next higher related counterpart in the periodic table of elements. Thus, the plant which is fed strontium will tend to use this element where and when it needs calcium providing no calcium is available. The strontium in this situation is known as an antimetabolite and is toxic because it is similar to calcium, while at the same time it is different and cannot actually replace calcium. This is also true for rubidium and potassium, arsenate and phosphate, and selenate and sulfate. This type of toxicity is similar to the effect of sulfa drugs in the treatment of disease caused by gram-positive pathogenic organisms which need p-amino-benzoic acid in their diet. In the absence of the normal metabolite the sulfa is toxic.

Data from Literature

Figure 1 shows the relationship between the concentration of mercuric chloride and the percentage of 5-day B.O.D. exerted by the sewage inoculum. At the low mercuric chloride concentrations, the increase in toxicity is slight in relation to the rate of increase in toxicity at the high mercury concentrations. It should be noted that the slope of the curve of toxicity against concentration for the chromate is the same as the slope of the curve for the low mercuric ion concentration and, further, that the slope of the curve of the toxicity *versus* concentration for the chromic ion is the same as the slope

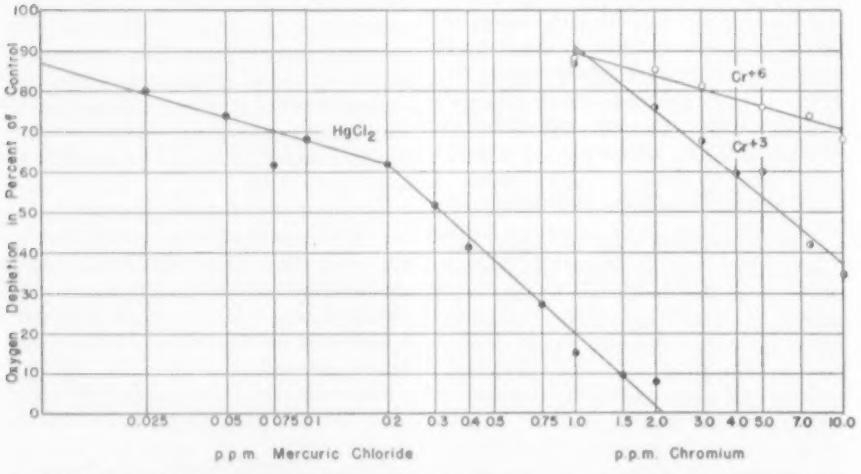

FIGURE 1.—Average values of 58 individual runs comparing the B.O.D. of sewage alone and sewage with various amounts of mercuric chloride, and of 20 runs comparing sewage alone and sewage with various amounts of chromium in the form of chromic sulfate and sodium chromate. (From reference (9).)

of the curve for the high mercuric ion concentration. It is pertinent to ask whether the slope of the curve is dependent upon the number of enzymes or enzyme-system pathways that are blocked by the specific ion. This speculation would indicate that the mercury takes out one enzyme or system below the break in the curve and two enzymes or enzyme systems beyond the break in the curve. There is also the possibility that the mercury in the low concentration range is affecting only the permeability of the cell membrane, whereas the higher concentration would indicate a second point of attack, possibly the cell interior or enzyme in the cell interior. The last hypothesis should be amenable to experimental verification; specifically, a 12 per cent reduction in the B.O.D. by the dilution technique will require 120 molecules mercuric chloride per volume of a bacterium (2-μ diameter sphere) or 40 molecules in a 0.1-μ thick layer outside the 2-μ sphere. Further, it will require 2,400 molecules of copper (per 2-μ sphere) and 46,000 (per 2-μ sphere) molecules of chromium for a 12 per cent reduction in B.O.D.

Relative Values

There are many factors affecting toxicity. A particular toxic substance has a specific toxicity for a given set of conditions, but the alteration of any one condition can greatly affect the apparent toxicity. Under conditions which are as nearly comparable as possible, 1.0 p.p.m. of each of the following will cause a given percentage reduction in oxygen utilization in a dilution B.O.D. test:

Toxic Agent	Reduction (%)
Mercuric chloride	80
Chromic sulfate	10
Sodium chromate	10
Copper sulfate	39

However, nothing is known concerning the effect of the previous environment upon these toxicity values, and the fact is known that biological accommodation to constant but originally small amounts of toxic substances can occur. Thus, many different biological forms can eventually accommodate large amounts of arsenic or methyl alcohol. Phenol is destroyed on trickling filters by biological oxidation when the fluctuations in concentration are not excessive and the initial dose is small.

Food Concentration

Further, the toxicity of mercury, chromium, and copper is markedly changed by increasing the food concentration where the oxygen utilization is measured by a direct-reading manometer. Thus, it has been shown (8) that at 1,000 p.p.m. B.O.D., 20 p.p.m. of chromium are needed to give a 10 per cent depression in the oxygen utilization. In general, the nature of the food added is not important in determining toxic effect of chromium expressed as the percentage reduction in the respiration rate of the bacteria. Thus, the amount and percentage of reduction in B.O.D. remains the same whether the added food is glucose or peptone. Similar data were found for sugar and methionine when tested with chromate under anaerobic conditions for utilizing nitrate oxygen.

Ionic Environment

The inorganic environment can also markedly affect the toxicity of a particular ion. Thus, the toxicity of strontium can be reduced by the introduction of the calcium ion which is normal to the organism (7). The ratio of the concentration of potassium to rubidium is also important in determining the toxicity of the rubidium. This is also true for reducing the toxicity of selenium by sulfur and of arsenate by phosphate.

The toxic effect of many substances results in an increased permeability of the cell membrane (15)(18). Thus,

the osmotic pressure of the environment, in relation to the internal salt concentration, can cause some changes in the energy requirements of an organism. Further, the metabolism of some organs or cells is markedly affected by the presence or absence of a certain ion, or a pair of ions, or the ratio of the concentration of each in a pair of ions. Thus, a physiologically balanced saline solution (such as a dilute sea water) will permit a higher metabolic rate at a given osmotic pressure and food concentration than is possible with the same osmotic pressure from any one salt. This would yield a different percentage-wise effect of a toxic ion, depending upon the ionic environment.

Internal Ionic Concentration

As Sawyer (17) points out, the concentration of a particular ion in the environment may limit the concentration of the toxic ion or substance that is to be studied. Thus, at pH 7.0, only 2 p.p.m. of copper can be dissolved in the dilution water recommended by "Standard Methods" (24). By reducing the pH to 6.5, 10 p.p.m. copper can be used in the phosphate concentration of the dilution water. The lower pH, however, gives slightly higher toxicity values to all copper concentrations.

Is it possible that the solubility constant of the copper and phosphate ions may be exceeded inside the cell and may account for part of the toxic reaction? This may be partially answered in the negative and positive by realizing that copper chelated by citrate (4) or lignin (11) is just as effective in controlling algae as the free copper ion whereas, on the other hand, the chelated copper is not toxic toward fish. Thus, Cuprose (cupric citrate) according to Black (1) is effective in controlling algae at Marineland, Fla., while it does not kill fish which are sensitive to the same concentration of the free ion.

Type of Organism

The nature of the plant organism itself may have some bearing on the toxicity of an ion. Nitrification is reported by Placak (12) and Jenkins (10) as preferentially depressed by chromate in the trickling filter, the activated-sludge process, and the B.O.D. test. Stone (22), on the other hand, reports that autotrophic nitrifying organisms are less affected by chromate than are the heterotrophic organisms. The literature is far from clear on this point. There is evidence from Fitzgerald (3) that autotrophic algae are less affected by a given concentration of toxic substance when the inorganic ion environment was more favorable for their growth. Thus, the relative toxicity of a given substance will depend upon the relative degree to which the environment would otherwise stimulate the organism.

Temperature is also important in controlling the percentage reduction of the metabolic rate by a given amount of mercuric ion. From the fact that many chemicals have negative temperature coefficients (like mercuric chloride), as shown by Van Esseltine (23), it is suspected that the other chemicals will show a percentage toxicity depending upon the proximity of the temperature to the optimum value. It is known, however, that sulfa drugs or antimetabolites become more effective as the temperature rises. This may mean that rubidium toxicity would increase with more favorable temperatures and with the degree of other favorable circumstances in the environment, except potassium.

Toxic Limits

What concentration of toxic matter can be tolerated? If an answer must be given to the question, then the following data must also be known:

1. Temperature of mixture.
2. Food concentration.

3. Inorganic ions—concentration and identity.

4. Nature and identity of the organism in the mixture.

5. Previous environment of the organism.

Some (22) have concluded that the only effect of food in the environment is the chelation or reduction in effective concentration of the toxic ion. This can be understood for the mercuric and chromic ions with proteinaceous food, but would it also hold for the chromate anion in the presence of sugar? I do not believe that sugar chelates chromate, but possibly this question can be answered with a biologically inert (stereoisomeric sugar) food in a medium instead of and along with the normal food (mannose compared with glucose for certain organisms).

It is my firm conviction that the observation of Fitzgerald (3) concerning algae is applicable to all simple organisms for many toxic substances. Thus, heterotrophic organisms are less affected percentage-wise by a given amount of certain toxic substances as the food concentration and other factors in the environment favorable to the organism are increased. However, the toxicity of certain antimetabolites may be increased in proportion to the increase in other favorable factors in the environment, except the one factor for which the antimetabolite substitutes, and when this factor is considered, then the generalization holds true.

Reduction of Toxicity

What can be done to alleviate the effect of toxic matter discharged to a sewage treatment plant? It is expected that removal of the toxic substance is an obvious and a good solution, but if arsenate is added to a sewer possibly an amount of phosphate four times the amount of arsenate can be added. This has been shown as a possible solution for reducing the toxicity of arsenate to wheat (7), but it is not known whether it will work for sewage treatment.

Rubidium is not common to industrial wastes, but strontium and selenium occur in some natural waters and may be found in a few wastes. Of course, rubidium may have an industrial application and, thus, may appear in an industrial waste at any time. Calcium is common enough in water that strontium toxicity may not be known because of the interrelationship of this pair. This may also be true for selenium and sulfur.

The general addition of salts to give an osmotic pressure more nearly equal to the internal saline concentration might be considered when ocean water is available for dilution in the sewage. This sort of suggestion would be possible for slugs, but would hardly seem wise for continuous additions, although it might prove economical under certain conditions. It would certainly seem worth study.

Should an increase in food concentration to a sewage treatment unit be considered? Hardly, for this would seem to defeat the whole purpose of treatment. It would be expensive and would throw other operating factors out of balance.

Can the temperature be increased? For the sludge digestion tank, the use of higher temperatures may be possible, but the general use of higher temperatures for an economical solution to sewage treatment itself hardly seems possible.

Cyanide

No mention of cyanides has been made thus far. The action of cyanides is so specific in knocking out the enzyme activity of the phorphorin-iron-bearing enzyme group that the cyanides are more nearly disinfectants than toxic materials under aerobic conditions. Nevertheless, some of the anaerobic processes continue in the presence of cyanides, so that those bacteria

capable of growing anaerobically continue to grow, while the strict aerobes must needs be dormant. Under anaerobic conditions the phorphorin-iron group of enzymes are inactive, so 30 p.p.m. cyanide, as shown by Ridenour (14), can be tolerated readily in a digestion tank, but at this concentration the supernatant liquid could be toxic or disinfectant to the aerobic treatment units. However, cyanide can be readily destroyed in sewage treatment by the addition of iron or by oxidation with chlorine at high pH. Further, the cyanides in low concentrations can apparently be oxidized biologically.

Higher Animals

A discussion of the general factors surrounding toxicity to fish must needs be brief, for many of the variables that can occur in the environment of microorganisms cannot be tolerated by fish. Thus, the food concentration of the fish cannot be suddenly increased a thousand-fold without the food itself of the microorganisms living thereon using all of the D.O. in the stream. Sudden changes in osmotic pressure are also difficult for some fish, although others (such as eels, shad, and salmon) normally migrate from one salt concentration to another, from ocean at 33,000 p.p.m. salt to a mountain stream of 20 p.p.m. salt.

The detoxification mechanism of the fish must also be considered, along with the general condition and defensive mechanisms of an individual. However, the degree of success in the defense by humans against the virus of poliomyelitis on the one hand and the bacterium of tuberculosis on the other hand is apparently dependent upon two diametrically opposed factors. The defense against tuberculosis is best in a body that is well nourished and rested, whereas the virus of poliomyelitis is apparently more successful under the same conditions. Thus, until the mechanism of toxicity of a particular substance against fish is known, factors which will affect the toxicity of a substance must be determined empirically.

As a general thing, however, it would be expected that a given amount of toxic substance will cause least fish damage when each factor in the environment is most nearly optimum, providing the fish has not just experienced a period of extreme fatigue (18).

Summary

A brief discussion of the many factors which affect the toxicity of a given substance has been presented. There are, in general, two types of toxic substances—those which are similar to normal cell constituents and are called antimetabolites, and those which are foreign to biological life. With those toxic substances which are foreign matter, the percentage reduction in the metabolic rate is progressively greater as the other factors in the environment become less favorable for growth. With the antimetabolites, the percentage reduction in the metabolic rate will be larger in the absence of the normal, corresponding substance where the other environmental factors approach the optimum values.

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AVAILABILITY OF NITROGEN IN SEWAGE SLUDGES

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Sewage sludges have been used as fertilizers for many years. Much of the information concerning their use has been summed up in a manual (1) published by the Federation of Sewage Works Associations. During the World War II, the supply of fertilizers in Great Britain became of increased importance and further work was carried out by Crowther and Bunting (2).

On the whole, less attention has been paid to the use of activated sludge alone than to digested sludge and raw primary sludge. This may be due to the greater difficulty of drying activated sludge in bulk, although some observers have recognized the superiority of activated sludge as a fertilizer over other sewage sludges. Higher quality effluents will be demanded during the next few years; therefore, more sewage works will be built and existing ones improved. As the activated sludge process is likely to be used in the larger works, it may reasonably be expected that considerable quantities of surplus activated sludge will become available which, when dried, would contain 6 to 8 per cent nitrogen and phosphate equivalent to 3 to 4 per cent of P_2O_5. At the Northern Outfall Works of the London County Council it is considered probable that, when the additional plant now under construction is completed, the equivalent of 2,000 tons of surplus activated sludge containing 3 per cent dry solids will be produced daily. At the Southern Outfall Works about half this quantity is likely to be produced. The London County Council has developed a process (3) for sludge freezing with added chemicals by which activated sludge can be dried efficiently, but one of the major factors governing the economic success of the process is the price obtainable for the finished product.

Although there is no doubt that prolonged field or pot tests would be the best way of establishing the value of activated sludge as a high-grade fertilizer, the tests would have to be extensive and would take several years to complete. The fact that a material contains a certain percentage of nitrogen does not indicate whether such a material would be of value as a fertilizer. Much depends on whether the nitrogen is in a form which would be converted to ammonia or nitrate in the soil and so made available to plants.

The availability of the nitrogen in a sludge is, therefore, a major factor affecting its value as a fertilizer. For this reason, the methods of estimating it recently put forward by Hamence (4) (5) have been studied with interest. Owen, Rogers, and Winsor (6) have worked independently along the same lines as Hamence and, in the main, their conclusions agree. The results given herein have been obtained by using the two methods put forward by Hamence, by which it is claimed that a definite figure can be given for the availability of nitrogen in a fertilizer.

First Method

In the method originally formulated by Hamence (4), a small quantity of the fertilizer, sufficient to provide 14 mg. N, is incubated at 22° to 23° C. with 200 g. of soil containing 20 per

TABLE I.—Soil from Epping Upland, Essex; 14 Mg. Nitrogen Added

Fertilizer Added to Soil	N (%)	Nitrogen (mg.)									
		6 Days		12 Days		18 Days		72 Days		100 Days	
		Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.
Blank	—	9.2	—	9.4	—	11.8	—	15.0	—	13.0	—
Dried blood	12.90	8.8	−0.4	12.1	2.7	14.8	3.0	22.1	7.1	15.8	2.8
Activated sl.	6.16	9.4	0.2	13.1	3.7	14.6	2.8	22.0	7.0	15.6	2.6
Activated sl.	5.67	9.8	0.6	15.2	5.8	14.5	2.7	22.2	7.2	15.9	2.9
Digested sl.	2.45	8.7	−0.5	14.4	5.0	14.2	2.4	23.0	8.0	15.8	2.8
Digested sl.[1]	3.08	8.7	−0.5	12.5	3.1	13.7	1.9	22.8	7.8	15.6	2.6
Raw sludge	2.66	9.2	0.0	8.8	−0.6	10.3	−1.5	16.4	1.4	12.9	−0.1

[1] Containing 1 per cent Al.

cent moisture and 0.1 g. of additional calcium carbonate. These conditions are regarded as giving the maximum nitrification and the nitrate formed is compared with that produced from dried blood under identical conditions, the availability of the nitrogen in dried blood being used as a standard of 100. The following modifications of the original method were used and were either suggested or agreed to by Hamence (7):

1. The amount of calcium carbonate used was increased from 0.1 to 0.2 g.

2. 0.5 ml. aluminum sulfate (62.5 per cent w/v) [*] was used, instead of 0.5 g. sodium sulfate, as the final coagulating agent.

3. The amount of water used to extract the 25-g. sample of soil after incubation was 75 ml. instead of 40 ml. This larger quantity of water enabled sufficient clear supernatant liquor to be obtained for a 40-ml. portion to be withdrawn without the use of a centrifuge. This 40-ml. portion contained one-half of the nitrate, for it should be noted that 5 ml. of water were present in the soil sample.

Small portions of the liquor also were tested for ammonia and nitrite. The nitrate was estimated after reduction to ammonia by Devarda's alloy.

[*] Grams per 100 ml.

Results

Some of the soils used for the preliminary experiments gave erratic results and poor conversion to nitrate. Ammonia and nitrite were present in considerable quantities in a few cases after 7 and 14 days. The choice of soil is, therefore, important and it was found that the best results were ob-

TABLE II.—Soil from Spalding, Lincolnshire; 14 Mg. Nitrogen Added

Fertilizer Added to Soil	N (%)	Nitrogen (mg.)					
		7 Days		14 Days		21 Days	
		Total	Avail.	Total	Avail.	Total	Avail.
Blank	—	14.0	—	14.9	—	17.1	—
Dried blood	12.90	18.0	4.0	22.7	7.8	23.5	6.4
Activated sl.	5.67	18.1	4.1	21.7	6.8	21.4	4.3
Digested sl.	2.45	14.5	0.5	16.6	1.7	16.8	−0.3
Raw sludge	2.66	11.6	−2.4	12.6	−2.3	15.5	−1.6

TABLE III.—Greenhouse Soil; Spring, 1953

Fertilizer Added to Soil	Composition		Nitrate Nitrogen (mg.)											
			7 Days		14 Days		21 Days		28 Days		35 Days		42 Days	
	Loss on Ignition (%),	Kjel. N (%)	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.
Blank	—	—	9.4	—	11.6	—	10.2	—	12.8	—	13.2	—	14.5	—
Dried blood	—	13.65	12.4	3.0	16.5	4.9	15.8	5.6	16.2	3.4	21.0	7.8	23.0	8.5
Activated sl.	78.8	6.02	14.0	4.6	15.6	4.0	14.1	3.9	15.9	3.1	21.8	8.6	19.5	5.0
Digested sl.[1]	58.6	2.54	10.8	1.4	14.8	3.2	11.8	1.6	11.8	−1.0	17.6	4.4	18.2	3.7
Raw sludge	69.0	3.24	10.1	0.7	12.5	0.9	12.5	2.3	13.4	0.6	17.2	4.0	16.2	1.7
Blank	—	—	9.9	—	11.3	—	10.6	—	12.2	—	12.0	—	13.9	—
Activated sl.[1]	79.1	6.41	12.7	2.8	17.0	5.7	15.3	4.7	16.4	4.2	16.6	4.6	18.6	4.7
Semi-dig. sl.	62.3	3.15	9.7	−0.2	14.4	3.1	13.9	3.3	14.4	2.2	13.4	1.4	14.5	0.6
Digested sl.	58.6	2.66	10.6	0.7	15.0	3.7	14.6	4.0	14.3	2.1	14.4	2.4	15.8	1.9

[1] Coagulated by freezing with alumino-ferric and filtered before air drying.

tained from soils which were in good condition or "good heart" and which permitted the formation of friable crumbs about 1/8 to 3/16 in. in size, when the water content was adjusted to 20 per cent.

The values obtained are given in the accompanying tables. Those in Table I were produced by a meadow loam from Epping Upland in Essex. The test was continued for 100 days owing to the small amount of nitrate formed in 18 days and, as pointed out by Hamence (4), was unreliable owing to the poor conversion of the nitrogen in the dried blood.

The soil used for the work in Table II was in very "good heart" and was taken from an arable field near Spalding, Lincolnshire. It was probably one of the most fertile fields in England and nitrate was produced rapidly from dried blood and from activated sludge. The nitrate maximum was at

TABLE IV.—Garden Soil from Worthing; Autumn, 1953

Fertilizer Added to Soil	Composition		Nitrate Nitrogen (mg.)											
			7 Days		14 Days		21 Days		28 Days		35 Days		42 Days	
	Loss on Ignition (%)	Kjel. N (%)	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.
Blank 1	—	—	12.1	—	12.0	—	14.8	—	14.7	—	15.0	—	16.7	—
Blank 2	—	—	12.3	—	11.0	—	15.5	—	14.0	—	14.8	—	16.3	—
Average	—	—	12.2	—	11.5	—	15.15	—	14.35	—	14.9	—	16.5	—
Dried blood 1	—	13.65	16.3	—	19.2	—	25.4	—	22.2	—	23.2	—	26.8	—
Dried blood 2	—	13.65	16.0	—	17.2	—	21.4	—	21.3	—	23.9	—	26.6	—
Average	—	—	16.15	3.95	18.2	6.7	24.75	9.6	21.75	7.4	23.55	8.65	26.7	10.2
Activated sl. 1[1]	79.1	6.41	16.9	—	17.6	—	21.4	—	19.8	—	20.7	—	24.9	—
Activated sl. 2[1]	79.1	6.41	17.2	—	16.8	—	21.9	—	20.7	—	21.8	—	24.8	—
Average	—	—	17.05	4.85	17.2	5.7	21.65	6.5	20.25	5.9	21.25	6.35	24.85	8.35
Digested sl. 1[1]	58.6	2.54	13.0	—	12.3	—	16.8	—	15.2	—	16.8	—	19.3	—
Digested sl. 2[1]	58.6	2.54	12.7	—	11.9	—	17.3	—	16.5	—	17.3	—	19.6	—
Average	—	—	12.85	0.65	12.1	0.6	17.05	1.9	15.85	1.5	17.05	2.15	19.45	2.95
Raw sludge 1	69.0	3.24	8.6	—	7.8	—	12.4	—	11.0	—	15.2	—	16.7	—
Raw sludge 2	69.0	3.24	9.1	—	7.8	—	13.6	—	12.9	—	14.5	—	16.9	—
Average	—	—	8.85	−3.35	7.8	−3.7	13.0	−2.15	11.95	−2.4	14.85	−0.05	16.8	0.3

[1] Coagulated by freezing with alumino-ferric and filtered before air drying.

14 days, when the conversion of the nitrogen in dried blood was 56 per cent, that in activated sludge 49 per cent, and that in digested sludge 12 per cent. The raw sludge had a negative value, having taken up the equivalent of 16 per cent of nitrogen from the soil.

Table III shows the results obtained from five different sludges after addition to a fertile greenhouse soil, which was then examined regularly for 42 days. The sludges used in all this work were dried in a current of air without heat and without other treatment, except in the case of one activated and one digested sludge. These two exceptions were frozen with alumino-ferric, giving a concentration of 1 per cent Al ion in each case on a dried solid basis, and were then thawed, filtered, and air dried.

Table IV gives values obtained from three sludges and dried blood when mixed with a garden soil from Worthing, Sussex. Each experiment was carried out in duplicate and two blank portions of soil were also used as a control. These results, shown graphically in Figure 1, were more regular than any obtained previously and reasonably close agreement was obtained with each pair of determinations of nitrate nitrogen. No trace of nitrite or ammonia was found in any sample at any time. Even so, the nitrate nitrogen in the blank sample did not increase steadily and in all samples a marked fall was observed at 28 days. The nitrate nitrogen increased in all samples at 35 days and again at 42 days. It is interesting to note that at 7 days about 28 per cent of the nitrogen in dried blood was available and 35 per cent from the activated sludge. The raw (crude)

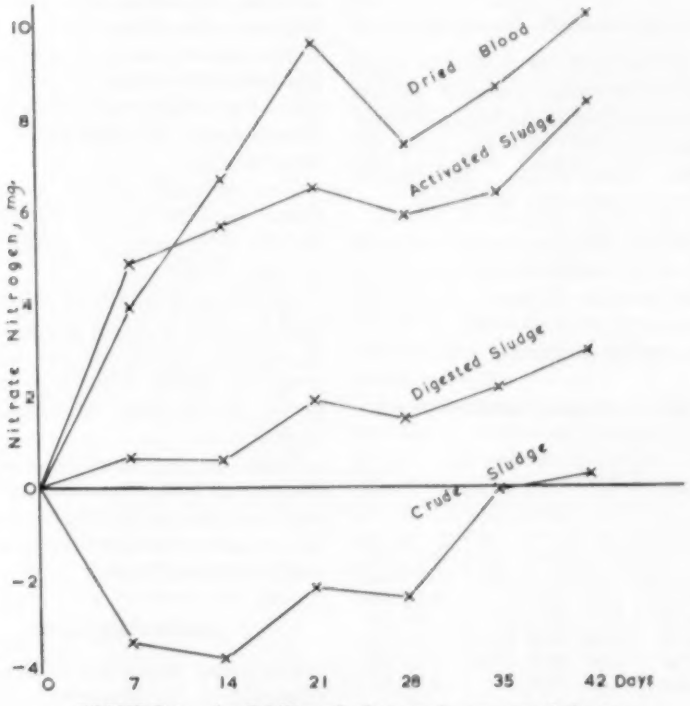

FIGURE 1.—Availability of nitrogen in sewage sludges.

sludge gave a negative figure until 42 days, when only 2 per cent of the nitrogen had become available. Other comparisons are as follows:

	Nitrogen Available (%)		Availability[1] (%)	
	21 days	42 days	21 days	42 days
Dried blood	69	73	—	—
Activated sludge	47	60	68	82
Digested sludge	14	21	20	27
Raw sludge	−15	2	−22	3

[1] Dried blood = 100 per cent.

These tests clearly establish the marked superiority of activated sludge compared with other sewage sludges as regards nitrogen availability.

The behavior of activated sludge in this way is, no doubt, due to its high protein content.

Second Method—Pepsin Test

As the soil test for fertilizers takes at least three weeks, a second method which is more rapid has been described by Hamence (5). He has now (7) modified this pepsin digestibility method to a procedure as follows:

1 g. of the fertilizer is incubated at 37° C. for 2 days with 50 ml. of a 1 per cent solution of pepsin in 0.3 per cent w/v hydrochloric acid. The insoluble matter is filtered off, washed well with water, and the nitrogen determined in the insoluble matter remaining on the filter paper.

TABLE V.—Pepsin Digestibility Test

Fertilizer	N (%)	Nitrogen (mg.)			Availability (%)
		Total	Residual	Available	
Dried blood	13.65	136.5	4.2	132.3	97
Activated sl.	6.16	61.6	22.9	38.7	63
Activated sl.	6.86	68.6	21.8	46.8	68
Digested sl.	2.45	24.5	18.7	5.8	24
Digested sl.	3.08	30.8	19.6	11.2	36
Raw sludge	2.66	26.6	16.9	9.7	36
Raw sludge	3.08	30.8	15.4	15.4	50

The results obtained with six sludges and dried blood are given in Table V. The pepsin test does not show that the nitrogen in digested sludge is more available than that in raw sludge. Although the test cannot give a negative value, which is known to occur in some cases, the positive values obtained for raw sludge appear to be larger than, and those for activated sludge less than, those obtained by the first method.

Summary and Conclusions

Laboratory soil tests with sewage sludges and dried blood have shown that nitrate is formed much more readily from activated sludge than from other sludges. In this respect, activated sludge compares with dried blood and can, therefore, be regarded as a high-grade fertilizer.

The pepsin test is considered to be less satisfactory than the soil test for use with sewage sludges, but clearly demonstrates the superiority of activated sludge.

Raw primary sludge was usually found to take up nitrate from the various soils employed in the test for at least 21 days.

The choice of a suitable soil for these tests appears to be an essential factor in avoiding erratic results, but a decrease of nitrate nitrogen is to be expected at 28 days when using this method.

Since the superiority of activated sludge has been demonstrated by the study of the availability of nitrogen, its phosphate availability might be studied with advantage.

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USPHS COMMISSIONED RESERVE TO BE EXPANDED

Expansion and reorganization of the Commissioned Reserve of the USPHS as part of an intensified civil defense program in the Service was recently announced by Surgeon General Leonard A. Scheele. The new program calls for recruitment of an additional 5,000 Reserve Corps officers by June 30, 1956, with 2,000 of that number being commissioned by June 30, 1955.

In addition to building up the Commissioned Reserve to emergency strength in line with expanded civil defense responsibilities, the Service is stepping up research in disaster health problems and is developing a program to reinforce state and local health departments in time of national crisis.

The Service has two fundamental objectives in strengthening the Commissioned Reserve. The first of these is effective emergency utilization of professional personnel with training and experience in public health; the second, augmenting of these forces with physicians and other professional people not normally working in the field of public health. Ultimate objective of the plan, according to Dr. Scheele, is the creation of a pool of trained physicians, sanitary engineers, nurses, and associated professional health personnel who can be immediately mobilized and selectively deployed to reinforce state and local health forces in times of emergency.

As the expansion gets under way, field training courses will be instituted for both present officers of the corps and newly recruited officers. Initial emphasis will be on the recruitment and training of physicians, nurses, and sanitary engineers.

Inquiries concerning commissions in the Inactive Reserve should be addressed to the Surgeon General, Public Health Service (P), U. S. Dept. of Health, Education and Welfare, Washington 25, D. C., or to the nearest regional office of the Public Health Service.

Industrial Wastes

ACCEPTABILITY OF INDUSTRIAL WASTES IN PUBLIC SEWERS *

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This paper is presented as a guide for sewage plant operators in the matter of discharge of industrial wastes to public sanitary sewer systems.

It is important that municipalities cooperate with industry and that all wastes that can be accepted into a sewer system and sewage plant should be taken in if the plant is of sufficient capacity and can successfully treat the waste. On the other hand, it is equally important that industry be made to recognize its responsibility in the matter of industrial waste discharges and treatment.

Numerous data are available (1) dealing with industrial waste and its discharge to a municipal sewer system. It is apparent, however, that no set rules can be established for the acceptability of industrial waste. Therefore, this paper is only presented as a general guide. To this end the paper outlines factors that should be taken into consideration and also includes a suggested method of admittance and/or regulation of industrial waste into a sanitary sewer system.

I. FACTORS IN ACCEPTABILITY OF INDUSTRIAL WASTE

There are many factors which influence the acceptability of industrial waste in public sewer systems. Some of the major factors can be summarized as follows:

1. Type of sewage treatment works.
2. Size of the receiving stream and its downstream use.
3. Quantity of waste and its relation to the size of the sewage treatment works.
4. Type of waste and its amenability to treatment.
5. Type of pretreatment.

Sewage Treatment Works

The type of sewage plant and the degree of treatment which the plant affords play a material part in deciding on the acceptability of the discharge of industrial wastes. The most common type of sewage plants can be generally broken down into the following broad classifications:

1. Primary treatment plants.
2. Intermediate treatment plants utilizing biological or chemical treatment processes.
3. Secondary treatment plants utilizing standard filters for biological oxidation.

* Presented at 1954 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; August 25–27, 1954.

4. Secondary treatment plants utilizing high-rate filters for biological oxidation.

5. Secondary treatment plants utilizing the activated sludge process for biological oxidation.

The order in which these sewage plants are set forth generally indicates the degree of their ability to accept any specific industrial waste when all other factors are considered equal. Inasmuch as primary plants employing only sedimentation remove a limited portion of suspended solids and B.O.D., but no dissolved solids, they will not be affected by many industrial wastes, since a large portion of dissolved organic and mineral matter is not removed and will be discharged to the receiving stream, thereby having a minimum of effect on the operation of the primary plant. On the other hand, a plant employing biological secondary treatment could be adversely affected by an industrial waste, since processes of biological treatment may be inhibited by the discharge of toxic substances in a waste, as well as by the discharge of a waste which is not as amenable to treatment as sanitary sewage. Sewage treatment works employing either standard filters or high-rate filters when subjected to a shock loading of industrial wastes will recover much quicker than a plant employing activated sludge.

There may be times, however, when the preceding order of secondary treatment plants might be reversed, especially when the amenability to treatment of a specific waste will be considered better in an activated sludge plant than in a trickling filter plant.

The type of sludge treatment could also play a part in deciding the acceptability of an industrial waste. As an example, primary treatment plants employing incineration of raw sludge will be able to accept metallurgical wastes in larger concentrations than plants employing sludge digestion This is because the accumulative effect of metals taking place in digestion tanks inhibits and retards digestion.

Size and Use of Receiving Stream

The size of the receiving stream and the stream use can play a material part in deciding upon the acceptability of an industrial waste. A sewage plant which has a water works and/or bathing places downstream would have to operate with very close control so that the effluent is of a standard good quality. With industrial waste of an erratic nature being discharged to a treatment plant in this situation, the effluent could be materially deteriorated at times. It might be conceivable, therefore, that there will be situations when it would be inadvisable to accept industrial waste proposed to be discharged to a sewage plant only because of the presence of a water works downstream.

The decision to accept industrial wastes where the stream use downstream requires close control on the plant effluent is one which a municipality would have to consider very carefully because in accepting the waste the municipality would assume responsibility for proper treatment thereof.

The size of the receiving stream always plays a material part in the degree of treatment which a plant must produce. It is obvious that plants on larger streams would usually be able to accept larger quantities of industrial waste, since the dilution factor on the plant effluent will be larger.

Relative Quantity of Waste

The quantity of waste and its rate of discharge will play a material part in the acceptability of that waste in the treatment plant, since each unit of the treatment plant has been designed either for certain rates of flow and/or certain pollution loading characteristics.

It is impractical to specify the amount of waste by percentage which can be admitted to a public sanitary sewer system because this will vary with many factors such as are being outlined in this paper, and each one is a case for separate study.

As an example, it is conceivable that a sewage plant may be able to accept up to 10 or 15 per cent of its capacity from such organic wastes as fermentation processes may produce, and yet when the loading of these wastes is extended beyond some threshold percentage, the sewage plant could be adversely affected to a point where it would not operate successfully.

The size of the sewage treatment plant will play a material part in the acceptability of industrial wastes. This is particularly true in the case of very large plants such as those serving large cities or metropolitan areas. These plants are not apt to be affected by large quantities of slug discharges from industrial plants because the slug loading from an industry could very well be counteracted by the shock loading from other industries and discharges from industries located a reasonable distance from the treatment plant will be ironed out, and diluted, by the travel in the sewer system. The fact that the plant is ex-

TABLE I.—General Characteristics of Process Wastes and Their Possible Effects on Sewage Treatment Units

Process Waste	General Characteristics	Sewage Treatment Units or Processes Which May Be Adversely Affected
Beet sugar	Excessive suspended inorganic solids and excessive dissolved organic solids	Grit chamber, settling tanks, biological processes, and sludge digestion
Brine	Excessive dissolved inorganic solids	None, within limits
Chemical, inorganic	Excessive inorganic dissolved solids may be toxic and corrosive	All biological processes and sludge digestion
Chemical, organic	Excessive inorganic solids, toxic and corrosive	All biological processes and sludge digestion
Chemical, pharmaceutical	Excessive inorganic solids, toxic and corrosive	All biological processes and sludge digestion
Coal preparation	Excessive inorganic suspended solids and corrosive	Grit chambers, settling tanks, and sludge digestion
Cutting oils	Excessive oils, scumming and coating constituents	All treatment units; scum-forming and coating possibilities
Dairy products	Excessive organic dissolved solids and excessive fats	Amenable to treatment; biological processes and sludge digestion
Fermentation: Antibiotics Brewing Distilling Winery Yeast	Excessive organic suspended and dissolved solids[1]	All biological processes and sludge digestion
Food canning	Excessive inorganic suspended solids, organic suspended and dissolved solids, and corrosive	Amenable to treatment; settling units, biological processes, and sludge digestion
Food dehydration	Excessive organic suspended and dissolved solids	Settling units, biological processes, and sludge digestion
Garages and filling stations	Excessive oils and greases	All treatment units by reason of scum-forming constituents
Gas manufacture	Excessive oils and greases and toxic	Settling units, biological processes, and sludge digestion
Meat packing	Excessive organic suspended and dissolved solids and fats and greases	Amenable to treatment; settling units, biological processes, and sludge digestion

TABLE I.—Continued

Process Waste	General Characteristics	Sewage Treatment Units or Processes Which May Be Adversely Affected
Metal fabrication	Excessive oils and greases	All units
Metal heat treating	Excessive toxic materials	Biological processes and sludge digestion
Metal plating	Excessive inorganic dissolved solids and toxic materials	Biological processes and sludge digestion
Oil refining	Oils, greases, toxic materials, and corrosive	Not amenable to treatment in biological processes
Paint manufacture	Excessive inorganic suspended solids	Settling units and sludge digestion
Paper making	Excessive organic suspended and dissolved solids	All biological processes and sludge digestion
Power laundries	Excessive organic dissolved solids and fats	Amenable to treatment; biological processes and scum-removing equipment
Rayon	Excessive dissolved organic solids	High causticity; may not be amenable to biological treatment
Rubber reclaiming	Excessive inorganic suspended solids	All settling and sludge digestion
Rubber, synthetic	Excessive organic dissolved solids	All biological processes and sludge digestion
Slaughter-house	Excessive organic suspended and dissolved solids, fats and greases	Amenable to treatment; all biological processes, scum handling, and sludge digestion
Starch manufacture	Excessive organic dissolved solids	All biological processes and sludge digestion
Steel manufacture	Excessive dissolved organic solids and corrosive	Settling units, biological processes, and sludge digestion
Tannery	Excessive inorganic suspended solids, organic suspended and dissolved solids	Settling units, biological processes, and sludge digestion
Textile	Excessive organic suspended and dissolved solids	All biological processes and sludge digestion
Wool scouring	Excessive organic dissolved solids and fats and greases	All settling, biological processes, scum-handling equipment, and sludge digestion

tremely large still does not allow it to accept any industrial waste in unlimited quantities, and there are times when even large plants are upset by the discharge of industrial wastes which should have been either pretreated or not discharged at all.

On the other hand, plants that are relatively small can accept only very limited quantities of industrial wastes and there will be many times when an industry, which could discharge its waste without any treatment into a large city treatment plant, would not even be acceptable under any conditions in a small treatment plant.

The capacity of a plant, whether it be of primary or secondary type, is important in determining the acceptability of an industrial waste. When a waste is under consideration for acceptability, the entire loading on the sewage plant, together with the capacity of each of the units in the plant, should be carefully evaluated and scrutinized to determine whether there is excess capacity available to handle a proposed industrial waste discharge.

Type of Waste

All industrial wastes do have some effect upon the operation of sewage treatment works processes. In considering amenability, certain measurable criteria must be developed. These criteria are measurable by adopted

methods of the engineers, the chemists, and other qualified personnel; however, no over-all empirical computation allows complete interpretation in each individual case. It is further recognized that considerable desirable data must be developed for the adequate consideration of the amenability of industrial waste to treatment with sanitary sewage, which in many cases may even necessitate experimental discharge to afford time for observations and for applicable measurements. In general application these criteria do afford basic factors for determining the acceptability of industrial waste for treatment with sanitary sewage, and do afford factors for pretreatment requirements.

Criteria for considering the amenability of industrial waste to treatment in sanitary sewage processes are as follows:

1. Uniformity:
   (a) Quantity or volume.
   (b) Rate of flow.
   (c) Composition:
      (1) Physical characteristics.
      (2) Chemical characteristics.
      (3) Combined mechanical-chemical characteristics.
2. Solids:
   (a) Mineral—inert.
   (b) Organic.
   (c) Mechanical.
3. Excessive acidity or alkalinity.
4. Toxic substances.
5. Scum-forming constituents (grease and oil).

With proper evaluation and interpretation of the criteria set forth, certain classes of industrial waste are immediately recognized as unacceptable to treatment in sewage treatment processes by reason of hazards and effects to the sewers and sewage treatment works. On this basis, industrial wastes not admissible to sanitary sewers are as follows (2):

1. Gasoline, cleaning solvents, fuel oil, etc.
2. Ashes, sand, cinders, etc.
3. Tar, plastics, and other viscous substances.
4. Mineral oils.
5. Feathers, hair, rags, etc.
6. Metal, broken glass, shavings, etc.
7. Unshredded garbage.
8. Toxic, corrosive, explosive, and malodorous gases.
9. Acetylene generation sludge, etc.

The classification of industrial waste in many cases allows the engineer the possibility of evaluating amenability according to a fairly well-adopted pattern. For instance, on a very general basis, for many years the following industrial wastes have been considered amenable to treatment with sanitary sewage:

1. Food processing wastes.
2. Milk processing wastes.
3. Slaughterhouse wastes.
4. Meat packing wastes.
5. Laundry wastes.

It must be recognized, however, that even in these instances each case requires individual study to determine if sufficient plant capacity is available.

For convenience in considering the details of acceptability of the classes of industrial wastes, Table I lists the process wastes together with their general characteristics and the possible effects which these process wastes have on sewage treatment works units.

Pretreatment of Industrial Wastes

The pretreatment of industrial wastes will in many instances allow the acceptability of such a waste when the waste would be inacceptable without pretreatment. Pretreatment can be generally broken down into the following broad classifications:

1. Equalization for uniformity of concentration and rate of discharge.
2. Provision for removal of excessive solids by sedimentation and/or fine screening, etc.

3. Provision for removal of excessive B.O.D.

4. Provision for the removal or reduction of toxic substances.

5. Provision for neutralization of excessive acidity or alkalinity.

6. Provision for reduction of scum-forming constituents.

The pretreatment which an industry must afford an industrial waste will have to be carefully coordinated with the sewage treatment plant capacity so that the reduction and/or ironing out of the loading by the preliminary treatment plant will be sufficient to allow the sewage plant to successfully treat the waste.

II. PROCEDURES FOR ACCEPTING INDUSTRIAL WASTES

Under this section there is set forth a suggested procedure for acceptance of industrial waste into the sewer system. Although this procedure is particularly suited to conditions in Pennsylvania, it could be modified or altered to meet conditions and rules and regulations of regulatory bodies in other states.

State Regulations

In Pennsylvania, sanitary sewer systems and sewage works are constructed and operated under permits issued by the State Sanitary Water Board, which has jurisdiction over all matters pertaining to stream pollution. The sewerage permits issued by the Sanitary Water Board are all subject to certain conditions, one of the conditions relating to the acceptance of industrial wastes and usually appearing in all permits being as follows:

> Attention is directed to the necessity of having a qualified person make proper study of all industrial wastes proposed for discharge to the public sewer system, to determine the degree of preliminary treatment, if any, which is necessary before these wastes may be discharged to the said system.
>
> No industrial wastes shall be discharged to the sewer system which will prejudicially affect the sewerage structures or their functioning, or the processes of sewage treatment, and any permission granted by the permittee for industrial wastes discharged into the sewer system should reserve to the permittee the right to regulate the rate of such discharge or to require such further preliminary treatment as may be necessary, or the exclusion of the said industrial wastes from the sewers, if this be deemed necessary to protect the permittee's interests.

Although the quoted standard condition usually appears in most sewerage permits, occasionally other special conditions relating to industrial waste are also included in Sanitary Water Board permits if special circumstances, design factors, stream conditions, etc., warrant the need for imposing additional limitations relating to the acceptance of industrial waste into the sanitary sewer system.

It should be noted from the quoted condition that while the Sanitary Water Board permit condition usually gives the permittee (that is, the municipality, sewer authority, or sewer company) the right to accept industrial waste, it specifically prohibits the acceptance of industrial waste which will "prejudicially affect the sewerage structures, or their functioning, or the processes of sewage treatment."

Regulation by Municipality

As a method of complying with the quoted condition and in order to control industrial waste discharge into a sanitary sewer system, the municipality, sewer authority, or sewer company should establish by ordinance, or by adopting rules and regulations, a system of procedure whereby industry will be required to do the following:

1. Make application to the municipality for permission to discharge,

either in the case of industries already connected or in the case of new industries desiring to connect.

2. Have a further study prepared by competent persons in the case of industries with major discharge problems.

3. After decision of acceptance by the municipality of major discharges, enter into an agreement defining and providing for regulation.

Application for Permission

The form used for making application for permission to discharge should be of a type which will secure certain basic information from the industry such as:

1. Name and address.
2. Type of industry.
3. Processes which produce industrial waste.
4. Listing the various types of industrial waste.
5. Characteristics.
6. Water consumption.
7. Waste quantities, rates of flow and methods of measuring.
8. Time of discharge.
9. Analysis of the waste.
10. Description of any pretreatment facilities, either existing or proposed.

The application form should be one which can be attested and signed by a responsible official of the industry.

The submission of such forms will immediately make available to the municipality a great deal of basic information as to the extent to which the sanitary sewer system is being used for industrial waste. From an evaluation of these application forms and by field investigation, the municipality can classify the connected industries into various categories. Some may be found to be of minor importance and permission can be granted immediately; others may have a major industrial waste problem and others may fall between these categories.

Further Study by Industry

Depending upon the degree of the individual case, and particularly where a major industrial problem is involved, the municipal authorities operating the sanitary sewer system should require the industry to retain a competent firm of consulting engineers, chemists, or other qualified persons to make a study of the industry's particular problem and to prepare a report with sufficient data to show that the industrial waste is or will be made acceptable for discharge to the sanitary sewer system. It is important that the consulting engineer, chemist, or qualified person retained by the industry have ample experience in industrial waste problems and sewage treatment processes. Even though they will represent the industry, their professional opinion as to whether the industrial waste will or will not adversely affect the public sewer system and sewage treatment works should be incorporated in their report. This report, together with the data on the application, can then serve as the basis for negotiating and for the municipality's issuing a permit or entering into a formal agreement with the industry for discharge of the industrial waste to the public sewer system.

Acceptance of Discharge

In the final analysis the municipal officials will have to make the final decision as to whether they desire to accept an industrial waste under consideration into the sanitary sewers, thereby assuming responsibility for the proper treatment and final disposal of such wastes. Obviously, such decisions should be based on recommendations of competent persons experienced in the art of sewage and industrial waste treatment. Some municipalities or sewer authorities may have such personnel in their regular employ, whereas others may find it advisable or necessary to retain qualified consultants for

that purpose. In addition, consultation with the local State Health Department officials is always appropriate.

Agreement or Permit

If the municipality or sewer authority operating the sewer system is willing to accept the industrial waste it can either then issue a permit of suitable form or enter into a formal agreement with the industry. Some of the stipulations which may be found desirable to include in such agreement or permit are the following:

1. Reference by title to the industry's consultants' report by name and date.
2. Stipulation of maximum quantity of waste permitted to be discharged per 24 hr. and the time and rates of flow.
3. Specific reference to the extent certain toxic elements or other harmful constituents must be reduced before discharge.
4. Construction of pretreatment works, if any, and proper maintenance and operation thereof at the industry's expense.
5. Submission by the industry to the municipality at appropriate intervals of records showing daily discharges to the sewer system, together with such chemical analyses as the municipality may deem necessary.
6. Reserve to the municipality the right to regulate the rate of discharge.
7. Reserve to the municipality the right to require such further preliminary treatment as may be necessary.
8. Reserve to the municipality the right to exclude the industrial waste from the sewer system.
9. Permit the municipality to have access to the industrial establishment to the extent necessary to observe and inspect operation of any pretreatment facilities and to inspect the sources of industrial waste.
10. Reference to charges for sewer service and that such charges are subject to future ordinances or regulations.

Regulation after Acceptance

When permission is granted for a sewer connection for industrial waste discharge the industry should appreciate that the problem is not altogether solved at that stage, but that work incident to controlling the rate of discharge and pretreatment, if required, must be faithfully carried out in the future and that such work should assume as much importance as any other operation in the industrial process. There have been numerous cases where failure on the part of industry to properly control volume and pretreatment practice has resulted in considerable difficulty at the municipal sewage treatment works. Sometimes the difficulty arose from change in operation personnel in the industry and failure to realize that the sewer connection was only intended to admit specific wastes and not intended for use as a general receptacle for every obnoxious and toxic waste in the plant, some of which should have been disposed of by other methods.

It would be advisable for the main operator or superintendent at any sewage treatment works, regardless of its size, to have some knowledge as to names and types of industries connected and the extent to which each is contributing industrial waste. Therefore, even when the foregoing recommended procedure for controlling industrial waste is being administered at the local governmental level, the records, applications, and supporting engineering reports should be accessible to the superintendent or operating head of the sewage treatment works at any time so that plant operation can be coordinated with administration. Responsible operating personnel should be encouraged to make periodic field investigations of those industries connected. This would not impose any unusual burden on operators at small

municipal plants because of the few industries connected. However, it is realized that in the case of the larger municipalities, cities, or joint sewer authorities, such field inspection work would probably have to be carried out by separate personnel.

Conclusion

If the suggested procedure outlined herein is followed, the information when finally collected and properly evaluated, together with a well-designed rate structure, will serve as a basis for making an equitable charge to industries for the treatment of their waste.

References

1. "Municipal Ordinances." Bibliography, Manual of Practice No. 3, Federation of Sewage Works Assns., Champaign, Ill. (1949).
2. *Ibid.*, p. 21.

PUBLIC SEWAGE PLANT CONSTRUCTION—1953

Because of greatly lessened stream flow in 1953, a year of extended and widespread droughts, pollution problems were correspondingly aggravated. What was done in the United States, in the form of contract awards, to help reduce pollution concentrations contributed by the country's municipalities, is tabulated in a USPHS report (Publication No. 409) under the title "Public Sewage Treatment Plant Construction 1953." The report supplements and brings up to date the information contained in the 1952 construction report (abs. THIS JOURNAL, **25**, 7, 786; July, 1953).

Progress made my municipalities during 1953 in providing sewage treatment facilities necessary to prevent pollution of water resources on which downstream water users depend is indicated by contracts amounting to $191,000,000 for 615 sewage treatment plants, including interceptor sewers in many places, awarded during the year. The cost of 329 new plants was $96,000,000, the remaining $95,000,000 providing for additions, enlargements or replacements for 286 existing plants. Comparison with the 1952 record reveals marked increases in four basins (Tennessee, Colorado, Great Basin, and Southeast) and a substantial reduction in only one basin (Northeast, where several large contracts for completion of the Boston area program accounted for almost one-half of the 1952 total).

Construction data are distributed according to the size of population groups to be served and the type of construction in Table I.

TABLE I.—Sewage Treatment Plant Construction Contract Awards in 1953 by Population Size and Type of Construction

Population Range	New Plants		Additions, Enlargements, Replacements, etc.		Total	
	No.	Cost ($1,000)	No.	Cost ($1,000)	No.	Cost ($1,000)
Less than 2,500	208	13,026	67	3,415	275	16,441
2,500– 5,000	40	7,854	36	3,883	76	11,737
5,000– 10,000	32	8,348	46	7,449	78	15,797
10,000– 25,000	28	14,188	42	8,429	70	22,617
25,000– 50,000	6	7,121	14	5,626	20	12,747
50,000– 100,000	7	13,398	17	15,342	24	28,740
100,000– 250,000	7	32,144	24	13,239	31	45,383
250,000– 500,000	0	0	10	5,842	10	5,842
500,000–1,000,000	0	0	7	5,998	7	5,998
1,000,000 or ovur	1	39	23	25,579	24	25,618
Total	329	96,118	286	94,802	615	190,920

INDUSTRIAL WASTES IN MUNICIPAL SEWERS—FLEXIBLE OR STRICT REGULATIONS *

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It is the purpose of this paper to discuss some of the more important considerations to be given to the establishment of regulations for controlling the discharge of industrial wastes into sewers. Nevertheless, all temptations to draw up a model ordinance are studiously avoided. In this connection it should be obvious that a single ordinance which will apply to all localities and situations cannot be drawn up because each individual situation is somewhat different from another, depending on such factors as the size of the municipality, the number and type of industries, and the nature of the treatment plant. Is should be noted, however, that there are instances where a regulation developed by a certain locality has been adopted by others without proper evaluation of its applicability to particular situations. Furthermore, the problem of sewer ordinances has many facets, including the questions of regulations pertaining to the use of public sewers by residential properties, regulations pertaining to private sewage disposal facilities, questions relating to house sewer connections, storm and surface waters, sewer rentals and financing. It is, therefore, necessary to set up certain limitations in scope. The problem is approached on the basis of broad principles, and it is limited to the specific question of what kind of regulations are desirable for the discharge of industrial wastes into sewers.

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It is the duty of a municipality or sewerage district to accept and treat all the liquid wastes arising within a sewage-shed, which do not cause any damage to sewers or affect the operation of the treatment plant. It may be necessary at times to exclude certain wastes, but this should not be done on an arbitrary basis but rather for good and valid reasons. The burden of proof in such cases should rest with the agency responsible for the treatment of wastes. To determine the acceptability of a waste a preliminary investigation should be undertaken, the cost of which should be borne by industry. The reasons in favor of including all wastes that can possibly be received are as follows:

1. It is more economical and feasible to treat a combination of wastes and domestic sewage than to treat each one separately.
2. The possibility of better supervision and control is greater in a combined plant than in a number of separate plants.
3. It relieves the industry from the responsibility of treating its wastes, which it is often not prepared or qualified to do.

In amplifying these reasons it should be remembered that often it is an advantage to treat industrial wastes in conjunction with sewage because the sewage affords dilution, reduction in toxicity, flow equalization and blending, chemical interaction, seeding, and nutrients. Waste treatment in a single combined plant is invariably cheaper than in separate plants because unit

costs for construction and operation are reduced as the size increases.

A larger combined plant can warrant the employment of better qualified men than can a number of smaller plants; as a result, better operation and control can be expected. In smaller industrial plants technical men qualified for waste treatment are not available and the job falls to a production supervisor who will naturally consider waste treatment as of secondary importance.

This right to discharge wastes to a public sewer system carries with it a number of responsibilities on the part of industry. Cooperation is the cornerstone for the success of such a project. It is essential that all information required as to the wastes, products, and processes should be unhesitantly furnished. There should be a willingness to aid the public agency in solving mutual problems. Industries should bear their fair share of the costs for collection and treatment.

What should be the guiding concept in controlling the admission of wastes into public sewer systems? There are three alternatives—namely, (a) no restrictions whatsoever and indiscriminate discharge; (b) very detailed, inflexible regulations; and (c) certain minimum regulations supplemented by flexible guides. With no regulation whatsoever, there is no protection for the industry, the sewer system, or the public. Therefore, this alternative can be dismissed without further discussion. The second alternative warrants some discussion, since there are many instances where regulations are spelled out in detail. Such cases may be justified if the treatment plant is badly overloaded, but many of these situations can be overcome by extension and expansion of the treatment facilities. If careful consideration is given to the problem of applying strict regulations, many incongruities and fallacies arise, as follows:

1. If regulations are drawn up on the basis of concentration of certain substances in the wastes without regard to volumes, it is conceivable that certain dilute wastes would be admitted and concentrated wastes would be excluded. Assuming a maximum limit of 500 p.p.m. in the regulation for suspended solids an industry with 1,000 p.p.m. suspended solids and with a volume of 10,000 g.p.d. would be excluded or required to pretreat, while another industry with 500 p.p.m. suspended solids in 20,000 g.p.d. would be permitted to discharge, despite the fact that both wastes contain the same total amount of solids.

2. If, on the other hand, regulations are based on the quantity of various substances discharged, then the question arises as to the basis on which the allocation to various industries will be made. Such allocation must either be arbitrary or on some inappropriate basis, such as the number of employees, taxes paid, etc. It will furthermore necessitate an elaborate system of controls to enforce such a regulation based on quantity.

3. Regulations based on the discharge of toxic substances on the basis of concentration in the waste are also fallacious because they do not take into account the dilution available after discharge of the waste, and toxicity is a question of ultimate concentration and total quantity of toxic materials in the sewage received, rather than individual contributions. The problems of regulation of the discharge of toxic substances are somewhat different from the previous illustration. Whereas, in the example given before the problem is one of capacity, toxic substances affect the efficiency of biological treatment processes. It is necessary to protect such processes by some kind of regulation. But if the regulation of toxic materials is based on concentration, it may not always give the desired protection or may unnecessarily ex-

clude minor contributors of toxic materials.

4. Strict, inflexible, detailed, unwarranted, arbitrary, overcautious regulations tend to make lawbreakers out of many industries and businesses, and are difficult to enforce although easy to apply. Strict limitations that are, in practice, unattainable, would tend to make industry disregard the valid portions of the regulations and be wary of voluntary cooperation with the sewage agency. The past experience with national prohibition is an appropriate illustration of this viewpoint. In order to enforce strict regulations, the agency must set up an elaborate program of sampling and analysis. This is seldom done. With the present status of knowledge concerning the effect of toxic chemicals on biological treatment processes, it is unwarranted to fix exact limits. The problem is too complex to be approached by oversimplified arbitrary methods. Standardized regulations are convenient devices to save lazy minds the trouble of thinking; they are often based on insufficient information, but they are seized upon, repeated, accepted, and adopted by others until they assume the semblance of authority. Yet there is no substitute for good judgment based on factual material in making decisions.

Not all failures in sewer systems can be attributed to poorly regulated industrial waste discharges. Many installations handling strictly domestic sewage have their problems arising from improper design and operation. This situation is often aggravated by the presence of industrial wastes. The existence of regulations *per se* does not necessarily guarantee avoidance of difficulties. Almost all regulations include provision for prohibiting the discharge of oil and inflammable and explosive materials. Yet is there a treatment plant which has not at one time or another received large quantities of oils? And sewer explosions occur all too frequently.

This leaves the third alternative—namely, certain minimal regulations supplemented by flexible guides to provide maximum protection on an equitable basis. There are certain concepts which should be included in any sewer ordinance and which should prove adequate without any specific conditions and requirements. These ideas are predicated on the principle that the regulatory agency has the right and will exercise its authority on the basis of factual information and seasoned judgment before reaching a decision on the merits of each individual case. The minimal regulations and supplemental guides can be divided into two categories: those pertaining to minimum basic restrictions and those pertaining to the implementation of any control program.

Restrictions on wastes discharged certainly should include the following:

1. No storm-water or surface drainage without special permission in separate systems.

2. No solid materials which will tend to damage structures or settle out in the sewers.

3. No oils, tars, greases, or other organic or inorganic materials which will tend to cling to the sides of sewers and impair their hydraulic capacity.

4. No oils, petroleum products, or other inflammable or explosive materials except by special permission.

5. No poisonous or toxic materials hazardous to life or to plant operation without special permission.

6. No materials which may be destructive to sewers or structures without special permission.

7. No wastes which create obnoxious conditions inimical to public comfort.

Items pertaining to implementation of the control program should include the following:

1. Requirement for all industries and businesses to register and furnish

information requested concerning their operations pertinent to their wastes and processes.

2. Requirement that all industries and businesses obtain permits for the discharge of wastes.

3. Provisions for revocation of permits and other penalties for infractions of rules and regulations.

4. Provision for rights of entry for purposes of inspection, sampling, and flow measurement.

5. Right to require pretreatment or flow equalization.

6. Right to prohibit discharge of wastes which cannot be tolerated in the sewers.

7. Right to levy special charges for treatment of industrial wastes.

The responsible authorities should be guided by the following principles:

1. When acid wastes are discharged, neutralization will be required provided the discharge of unneutralized waste causes the pH in the lateral sewer to go below 4.5. Also, sewage received at the plant with biological treatment processes should not have a pH below 6.0. For other types of treatment the pH should not be below 5.0.

2. When alkaline wastes are discharged, there is no need to neutralize provided the pH of the sewage received at the plant does not exceed 8.5.

3. In general, temperature of the wastes discharged is a minor problem, and except in cases where relatively large volumes of wastes at high temperatures are suspected of causing damage, their flow or temperature should not be regulated.

4. Although no straight oils, tars, and greases, or concentrated emulsions thereof, are allowed, it is difficult to exclude small amounts of such materials originating from washing and cleaning operations. For instance, garages should not be allowed to discharge crankcase oil into sewers; however, certain amounts of such oils are bound to enter into sewers through washing operations.

5. There is no need to restrict the specific gravity or size of suspended solids discharged, beyond the requirement that they should not settle out in sewers.

6. There is no need for fixing an upper limit for suspended solids and B.O.D. concentration of a waste, provided there is adequate capacity at the plant. If the capacity is limited, it is advisable to restrict the discharge on a pounds-per-day basis compatible with capacity.

7. In rare instances it is necessary to restrict the concentration of dissolved solids. These restrictions are often meaningless because the concentration of dissolved salts in sewage is affected by the variations in the dissolved salts in the water supply.

8. Normally there should be no restrictions on total volume or rate of waste discharged except in unusual cases where the sewer and plant hydraulic capacities are adversely affected.

9. Equalization of discharge or controlled discharge during off-peak periods may be required when fluctuation in flow and concentration affect the treatment facilities adversely.

10. Pretreatment may be required for wastes that affect the operation of the plant adversely, either due to lack of capacity or for the purpose of removing some substances inimical to collection or treatment.

11. Admission of substances toxic to biological treatment processes or receiving streams should be on the basis of the concentrations in the sewage received at the disposal plant and their effect on the treatment processes on the basis of the best available information. Such information was brought together by the Research Committee of the Federation (1). Additive or counteractive effects of combinations of a number of toxic substances are not well known.

12. Phenols are known to be destroyed by biological action in treatment plants and streams at relatively high concentrations. Unless such concentrations are exceeded or the stream is used as a water supply, there is no need to restrict the concentration provided the plant effluent will meet the requirements of stream regulatory agencies.

13. Chlorine demand should not be a basis of restriction unless chlorination is adversely affected. This is normally a question of chlorinator capacity and cost of chlorine, which can be adjudicated on an equitable basis.

A flexible control program must have a firm foundation based on adequate information. A simple application form should suffice for most of the industries and businesses in a sewageshed and should include the following:

1. The name and location of each factory and business served.

2. The type of business, products manufactured, raw materials used in processing, and general information concerning the processes or operations involved.

3. The number of employees contributing to the sewer system.

4. The amount of water used by the plant, or the sewage discharged. Also, some estimate of the peak flows encountered and the maximum daily flows.

5. A diagram showing the points of discharge of the property sewers into the sewer system.

Additional information will be necessary from industries whose operations are complex or whose wastes will have a significant effect. Size of the industry is not necessarily a good criterion for making further investigations, because a small industry might possibly discharge very difficult wastes. The size of the industry requiring special study will also be in relation to the size of the sewer system.

For these industries more elaborate measures may be necessary. They include:

1. An investigation of the premises and processes by representatives of the public agency.

2. More extensive information from the industry regarding the processes and the wastes produced. Such information to be special and specific for each particular industry.

3. A program for taking waste samples, making necessary analyses. Collection of such information should be the responsibility of the public agency, and the cost of specialized analyses beyond the scope of the agency should be borne by the industry. It is understood that many small treatment plants will not have the facilities and personnel for making such analyses. In these cases, help should be available from organizations such as state health departments, water pollution control agencies, universities, and commercial laboratories.

4. In order to make all the information gathered meaningful and readily available for tracing out the source of waste difficulties it should be systematically filed, catalogued, and, if possible, cross referenced. One obvious help, of course, is the spotting of all listed industries and businesses on the master sewer maps, showing their connections to the sewer system and being identified by some special designation.

Summary

A discussion is presented on the basis of broad principles and general concepts for a rational approach to the problem of regulations pertaining to the admission of industrial wastes to public sewers. Wherever possible, such a principle should be encouraged, under proper safeguards. However, the safeguards and restrictions should be on the basis of *bona fide* or potential danger to human life and comfort, to sewer and sewage plant struc-

tures, and to the operation of the treatment plant.

Furthermore, it is the responsibility of the public agency to implement these safeguards by excluding certain wastes from public sewers or to require certain modifications and pretreatment, but the burden of proof rests with the agency. For this purpose, it should be the duty of the public agency to obtain, by a regular sampling procedure, the information and evidence necessary to prove damage.

The regulations should be flexible and drawn on broad terms, rather than detailed specific rules, so that each case can be decided upon on the basis of its merits after careful and reasonable consideration. It is not sufficient to consider only the volumes and concentrations of the wastes discharged and make the restrictions on the basis of concentrations in the waste, but consideration also must be given to the volume in the receiving sewer, the dilution available, and the concentrations received at the treatment plant.

Industry itself has certain responsibilities, such as furnishing required information, cooperating with public agencies to solve mutual waste disposal problems, and bearing its share of the cost of treatment.

The suggested approach to regulation of industrial waste discharges into sewers replaces fixed specific rules and regulations. Such an approach can be easily promulgated by judgment and discretion of a high order.

Reference

1. Rudolfs, W., *et al.*, "Review of Literature on Toxic Materials Affecting Sewage Treatment Processes, Streams, and B.O.D. Determinations." THIS JOURNAL, **22**, 9, 1157 (Sept., 1950).

KRAUSE REPLACES HITZROT AS DIRECTOR OF BDSA WATER AND SEWERAGE DIVISION

The appointment of Charles W. Krause, of Glen Rock, N. J., as Director, Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, U. S. Department of Commerce, was announced November 30, 1954, by BDSA Administrator Charles F. Honeywell.

Mr. Krause, New York District Manager of the Neptune Meter Co., is on loan to BDSA from his company under a rotation system whereby outstanding business executives serve the Government without compensation for periods of 6 months or longer.

He succeeds Henry W. Hitzrot, of The Dorr Co., Westport, Conn., who has served with BDSA since March 1954 and will continue his association with the agency as a consultant on matters pertaining to water and sewerage.

IN-PLANT CONTROL OF DAIRY WASTES *

By Clifford W. Watson, Jr.

Sanitary Engineer, Dairymen's League Cooperative Association, Inc., New York, N. Y.

After World War II many states either passed new anti-pollution laws or strengthened existing laws. At the Federal level, the Water Pollution Control Division of the U. S. Public Health Service was created by Public Law 845 of the 80th Congress during 1948. Its chief function is the promotion and stimulation of pollution abatement through cooperative programs, research, and advancement of funds for use by the several states. It has authority with respect to interstate waters to act if states fail to do so.

Dairy Industry and Clean Streams

The dairy industry, with plants scattered throughout the 48 states, has felt, to a considerable extent, the effect of these clean streams movements. The problem was of such a magnitude that a national committee known as the Subcommittee on Dairy Wastes of the Dairy Industry Committee was formed. Its purpose is to study the problem, gather data that will be of assistance to the dairy industry, and disseminate it for the use of the entire industry. As with many other industries, it was felt that the best place to attack the problem of pollution was at the source. With this in mind the committee published a manual for dairy plant operators entitled "Waste Prevention in the Dairy Industry."

The sources of waste in a dairy plant fall into about seven general classifications as follows:

1. Leakage.
2. Overflow.
3. Spillage.
4. Freezing on.
5. Willful waste.
6. Residual waste.
7. Carryover.

Each source of waste may contribute considerably to the waste load from a plant. Each source is also controllable.

Waste in the Dairy Plant

Leakage may occur at pumps, sanitary pipeline fittings, plate heaters and coolers, clarifiers, separators, homogenizers, and filling machines. For the most of these, a program of maintenance throughout the plant will eliminate many leak sources. Often, however, a leak may occur in a pipeline or piece of equipment during the operation that cannot be corrected at once. In cases of this sort receptacles such as pails, etc., should be available around the plant to catch these leaks and keep them from entering the sewer. A new feature recently introduced in the milk industry that will prevent many pipeline leaks is in the in-place system of cleaning sanitary pipes. In this system a new type of sanitary fittings, together with a leak-proof gasket of neoprene or similar material, is used. Pipelines may first be rinsed and the rinsings collected instead of going on the floor as is the case where pipelines are taken down for washing each day.

Overflow may occur at many points in a dairy plant, such as receiving tanks, storage tanks, vat pasteurizers, hot wells, and cheese vats. An example

* Presented at 1954 Annual Meeting, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; August 25–27, 1954.

of spillage occurred recently in a Dairymen's League plant where the waste was being treated with an aeration-type treatment plant. A complaint was received from the manager that the treatment plant could not be operated continuously and became septic. Investigation of this situation revealed spills at the receiving vat. During the period of the investigation five spills were recorded through the raw waste sampling. The samples indicated a loss of milk above the normal average in the plant waste of 1,880, 268, 492, 176, and 330 lb., respectively. They were found to have been caused by a faulty heater coil in the starter for the pump emptying the receiving vat, causing the pump not to operate when the start button was pushed. At the current price of milk ($4.06 per 100 lb.) these spills caused a loss at this plant of about $127.89. This example shows the value of level controls that signal the operator when a vat or tank is full.

Poor Equipment Design

Spillage of product to the floor is generally a result of careless handling or improper equipment design or layout. An example of this occurred recently in a New Jersey plant. A condition of excessive spillage occurred at a two-compartment western-type dump weigh can with a swinging hopper. When the hopper was over the left side of the weigh can, a portion of the milk dumped struck the projection on the side of the hopper under the can track and spilled over onto the floor. This was corrected by adding a piece of stainless steel to the end of the projection and bending it back 180°. Thus, the milk that formerly spilled on the floor was thrown back into the weigh can.

Freezing on occurs mainly on cooling equipment, ice cream freezers, and in farmers' cans during severe winter weather. The product frozen on the equipment is removed during the general cleanup of the plant or washing of farmers' cans in a can washer. An example of the seriousness of frozen milk in farmers' cans showed up during a survey of a receiving plant in Pennsylvania. The waste survey showed an average B.O.D. of 21.7 lb. per day, or a loss equivalent to about 210 lb. of milk. During the period of survey there were three days that the temperature ranged around 0° F. The average B.O.D. for these three days was 55.6 lb., with one day as high as 73.8 lb., indicating a loss from 2½ to 3½ times the normal volume of milk entering the sewer. The additional milk in the waste was, of course, all caused by frozen milk in the farmers' cans removed in the can washer. The answer to this problem is the transportation of farmers' milk to the receiving station in insulated vans. This procedure is required in some areas by law and in many others is becoming a general practice to protect the farmers' milk.

Willful waste, as the notation indicates, is the wasting of products for which there is no market and for spoiled products. A prevalent example of this is the wasting of cheese whey from a cheese operation. This, however, is becoming overcome through research to find new products into which such by-products of an operation can go. It also has been found that irrigation of land is a profitable use for this material and many companies are finding it both advantageous and profitable to do this.

Most Troublesome Source of Waste

Residual waste is by far the most troublesome. It occurs in all milk plants and adds to the pollutional load of a plant's waste, to a greater or lesser degree, depending on the care taken to collect it. Residual milk is that milk which clings to the walls of a can or piece of equipment that must be washed out after each day's use. The

TABLE I.—Waste Milk Analyses

Item	Plant		
	Leonardsville	Cazenovia	New Woodstock
Atomizer rinse	Yes	Yes	No
Drippings coll. at can washer (lb./day)	85	217.5	59.5
Rinsings from milk lines, etc. (lb./day)	85	157.2	162.0
Drippings test:			
Fat (%)	3.631	2.73	3.63
Fat (lb.)	3.09	5.94	2.18
Total solids (%)	11.10	7.60	10.63
Total solids (lb.)	9.43	16.53	6.44
Rinsings test:			
Fat (%)	2.246	1.99	2.14
Fat (lb.)	1.91	3.13	3.47
Total solids (%)	6.68	6.50	4.97
Total solids (lb.)	5.68	10.22	8.05
Fat collected (lb./day)	5.00	9.07	5.63
Total solids collected (lb./day)	15.11	26.75	14.49
B.O.D. kept out by waste saving (lb./day)[1]	12.1	21.2	11.58
Total B.O.D. in effluent waste (lb./day)	11.57	26.11	16.57
Total B.O.D. in effl. without saving (lb./day)[1]	23.67	47.31	28.15
B.O.D. in effl. waste (lb./day/10,000 lb. milk)	5.02	3.64	4.95
B.O.D. kept out by waste saving (lb./day/10,000 lb. milk)	5.25	2.96	3.46
B.O.D. received without waste saving[1] (lb./10,000 lb. milk)	10.27	6.60	8.41
B.O.D. removed by waste saving (%)	51.1	45.0	41.1

[1] Estimated on basis of 1 lb. total solids = 0.8 lb. B.O.D.

Dairymen's League recently surveyed three receiving plants to determine the value of waste saving during normal operation. Each plant was equipped with a dripsaver on the can washer to catch the residue in farmers' cans after dumping, and utensils to catch drips and collect milk remaining in equipment prior to washing. Each plant also had a weir box in the sewer line equipped with an automatic sampler to sample the waste. The results of this survey are given in Table I. Another survey was conducted to determine the effectiveness of drip savers on can washers. Each plant was equipped with a drip saver on the head end of the can washer without an atomizing rinse. The results of this survey are given in Table II. These surveys readily show that a waste prevention program in any milk plant can materially reduce the pollutional load of its waste.

Carryover occurs in evaporating equipment. Milk is evaporated in vacuum pans under high vacuum. The vapor produced during the boiling process is removed from the top of the vacuum pan and passed through a water-cooled condenser. In the boiling process, should it become too violent, small particles or drops of milk are thrown up and become entrained in the flow of vapor to the condenser. This condition may most effectively be corrected through the use of an entrainment separator, consisting of a series of baffles over which the vapor must pass before reaching the condenser. As the vapor passes around the baffles the entrained drops of milk are lost and flow back into the vacuum pan. The Hershey Chocolate Company in their manufacture of milk chocolate operated a number of vacuum pans. A check of the condenser water indicated that the B.O.D. varied from 30

TABLE II.—Milk Collected in Drip Saver

Plant	Milk Collected		
	Per Can (oz.)	Total (lb.)	Per 10,000 Lb. Dumped (lb.)
Middleville	2.44	55.5	25.8
Nicholson	2.7	58.5	24
Pleasant Mt.	2.4	124	22
Prattsville	3.12	87	28.6
Springville	2.34	134	20.6
Union City	2.38	124	24.5
Wyalusing	2.8	142	26
Average	2.6	—	24.5

to 90 p.p.m. Subsequent installation of entrainment separators on the vacuum pans reduced the B.O.D. to less than 2 p.p.m., showing a substantial reduction in the pollutional load of the plant effluent to the stream.

Equipment Improvements

Many improvements in milk handling equipment, other than the drip saver on the can washer, have reduced materially the loss of milk to the sewer. Some of these include whey savers on cheese vats, with sanitary connections to prevent whey spillage to the floor; automatic bottle casing equipment, which cuts loss by full-bottle breakage to a minimum; and many others.

A point not too often thought of as an anti-pollution move is the consolidation of receiving plants. With the improvements in transportation and the economics involved in milk handling becoming an extremely important factor in the marketing of milk, many local receiving plants are being closed in favor of a centralized operation. An example of this is the Dairymen's League operation at Horseheads, N. Y. This is a manufacturing plant producing a variety of products, such as milk powder, cream, ice cream mix, etc. Previously a portion of the milk manufactured came in direct delivery in farmers' cans. In addition, there were three feeder plants located within a radius of 20 mi. where the milk was received from the farmers, cooled, placed in tanks, and subsequently put into a tank truck for delivery to the manufacturing plant. Now the three feeder plants have been closed. Additional cooling facilities have been installed on the farms for cooling morning milk and the milk is now picked up later in the day for delivery directly in insulated trucks to the manufacturing plant.

Another feature recently introduced in the dairy industry that will aid in elimination of stream pollution is the bulk pick-up system. This again aids through the elimination of the receiving plant. With this system milk is pumped directly from the farmers' refrigerated holding tank to a tank truck, in which it is transported directly to the processing plant, eliminating the receiving plant.

Waste Milk Dairy Operation

Many ways have been devised for collecting milk that would normally be wasted to the sewer, but the means of disposal poses another problem. This collected milk is valuable, having both a high butterfat and total solids content. It can be used for animal feed, but a plant manager dare not discriminate by giving it to one farmer and not another. The problems of about 135 plants in North Central Pennsylvania and South Central New York have been solved with the formation of a dairy organization known as Conservation Creameries, Inc., located at Little York, N. Y. This company was organized and a plant started up for the express purpose of collecting the waste milk and processing it into butter and non-fat dry milk solids for use in animal feed. At present the amount of milk collected averages 20,000 lb. per day, with two-thirds of it testing 3.5 per cent butterfat and one-third testing about 1.8 per cent butterfat. The daily yield from this milk amounts to about 600 lb. of butter-

fat, which is made into 92-score butter. The skim milk is made into roller process powder and yields from 800 to 1,000 lb. per day. It is estimated that this concern alone eliminates approximately 1,700 lb. of B.O.D. from the streams daily, or a population equivalent of more than 10,000 persons.

Waste Control Program

Waste prevention in the dairy plant has a definite place in the over-all waste control program. However, the success of such a program depends on the personnel responsible for it. In setting up a waste prevention program the equipment must first be on hand to do it. Secondly, an educational program must follow to explain the use of the equipment and to develop interest in the program. After the program is in operation the third step is check-up. This is best done by waste sampling and comparing the results with the published standard losses for the operation taking place, advising the plant personnel of the results. An efficient program of waste prevention often may be all that will be necessary to comply with state pollution control authority requirements.

DISCUSSION

By C. L. Siebert, Jr.

Chemical Engineer, Pennsylvania Department of Health, Harrisburg, Pa.

Mr. Watson has treated ably the sources and extent of dairy plant wastes, and various methods of correction or reduction. In his tabulation of the waste losses at three New York State plants (Table I), he has shown reductions of from 11.5 to 21 lb. B.O.D. per day. How much is a pound of B.O.D. worth in terms of the construction cost of a waste treatment works?

Eight dairy waste treatment works in Pennsylvania on which cost and performance data are available to the State Health Department (Table III), ranging in design B.O.D. loads from 10 to 150 lb. per day, and in cost from $3,800 to $30,000, showed a range of investment of from $200 to $2,000 per pound of daily B.O.D. removed, with an average of $800 per pound. This rep-

TABLE III.—Construction Cost Comparison for Eight Dairy Waste Treatment Works in Pennsylvania

Plant	Year Built	Constr. Cost ($)	B.O.D. (lb./day)		Cost ($/lb. B.O.D. rem.)	Waste Volume (g.p.d.)	Cost ($/g.p.d.)
			Raw	Removed			
A	1939	$30,000	35	34.7	865	3,613	8.3
B	1950	21,000	10.6	9.6	2,190	2,275	9.2
C[1]	1947	3,800	20.1	8.8	432	2,041	1.9
D	1949	28,000	20.7	20.5	1,370	5,726	4.9
E	1952	9,500	17.8	17.1	555	3,070	3.1
F	1950	10,000	20.3	19.4	515	6,800	1.5
G	1952	20,000	75	71.3	280	15,000	1.3
H	1952	18,000	150	101.5	177	20,000	0.9
Minimum					177		0.9
Maximum					2,190		9.2
Average					798		3.89

[1] Splash plate aeration only.

resents construction cost only, and does not take into account any operating costs. The waste saving procedures effected in the data presented by Mr. Waston would indicate a reduction in treatment works cost of $9,600 for Leonardsville, $17,000 for Cazenovia, and $9,250 for New Woodstock. In the particular case of Dairymen's League, it is believed that actual plant construction cost run lower than the $800 per pound of daily B.O.D. previously indicated, because that company has studied and tried a number of designs, and has now evolved a standardized type of construction which involves a minimum of new engineering for each job, allows cost saving by construction experience, and provides for interchangeability of pumps, blowers, and other equipment. However, the cost of $800 per pound of daily B.O.D. removed is about what an average company should expect to pay for the construction of dairy waste treatment works. It can be seen that waste saving is certainly worth some effort.

Another relation, on a volume basis, can be worked out with the same data. A range of from $1 to $9 per daily gallon of waste is indicated, with an average of $4.00 per gallon.

In the matter of saving by actual product recovery, waste saving does not always produce a return at the full price of milk, but some improvement of plant yield is almost certain to follow an efficient waste saving program.

Mr. Watson referred to the installation of entrainment separators at the plant of the Hershey Chocolate Company. Some additional figures on that installation may be of interest. The Hershey Chocolate Company processes 1,000,000 lb. of milk per day. The installation of entrainment separators saved 3,000 lb. of milk and 1,000 lb. of sugar per day, sweetened condensed milk being produced at this particular plant. With milk at $4.00 per 100 lb. and sugar at $0.085 per pound, the daily saving of product by the separators is about $205.

This writer expresses full agreement as to the desirability of using insulated vans to transport milk to receiving stations. At least in the colder parts of Pennsylvania, there are many days each winter when considerable milk is lost by freezing in cans transported on open trucks, even when using tarpaulin covers. The writer has observed more than one waste treatment works overloaded in the winter to the point of ineffective operation, because of freezing on cans so transported to the plant.

The bulk pick-up system is one which may well have a marked influence upon the dairy industry, and also upon the control of stream pollution. Not all of the pollution aspects, however, are pleasant. Unless the farmer is especially conscientious, or fearful of the law, the bulk system may encourage the dumping of milk wastes to the stream at each individual farm. True, this would spread pollution thinner, but possibly not thin enough. It would also make control much more difficult.

Finally, in almost any discussion of dairy waste saving there is introduced the proposition that saving can be practiced to the extent that construction and operation of waste treatment facilities can be avoided entirely. Yes, this can happen, but it is misleading to express great optimism in this connection, or to infer that waste saving alone is the solution in the majority of cases.

BACTERIAL STUDIES IN OXIDATION OF PHENOLIC WASTES

By G. E. Lynn and T. J. Powers

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Recent articles (1) (2) (3) on the biologic oxidation of oil industry phenolic wastes have led to the belief that the results of the Dow Chemical Company's 1936 bacterial identification work may even now be of some help to others as it was to the authors at that time.

The pilot plant had operated for some 11 months when the study was made and the time for decision on large-scale facilities was drawing near. As a result of this study two important matters were resolved, as follows:

1. There was a more confident acceptance by management of the feasibility of biological oxidation as a treatment method for phenolic wastes.

2. The process could be operated without sanitary sewage for seed, hence a cheaper and simpler design was possible.

The full-scale plant was designed and built so that operations began in October 1937. These facilities have been reported previously in the literature (4).

The pilot plant (Figure 1) consisted

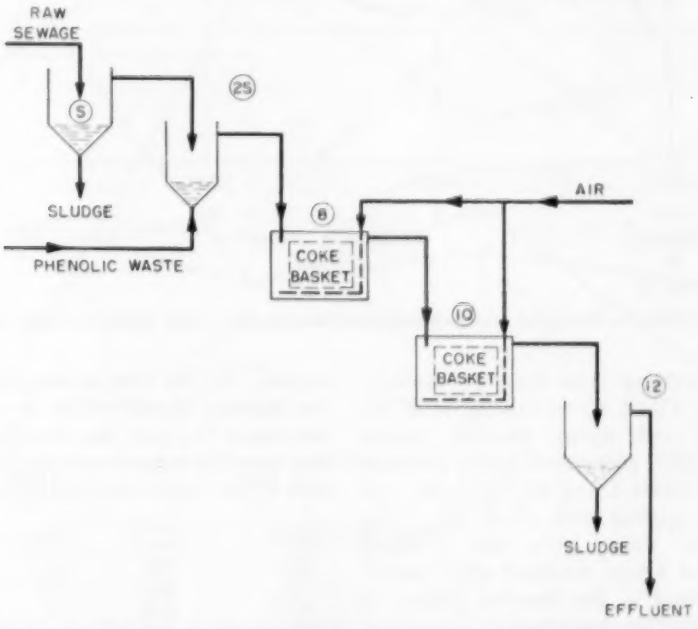

FIGURE 1.—Flow sheet for phenolic waste treatment pilot plant, Dow Chemical Co., August, 1936.

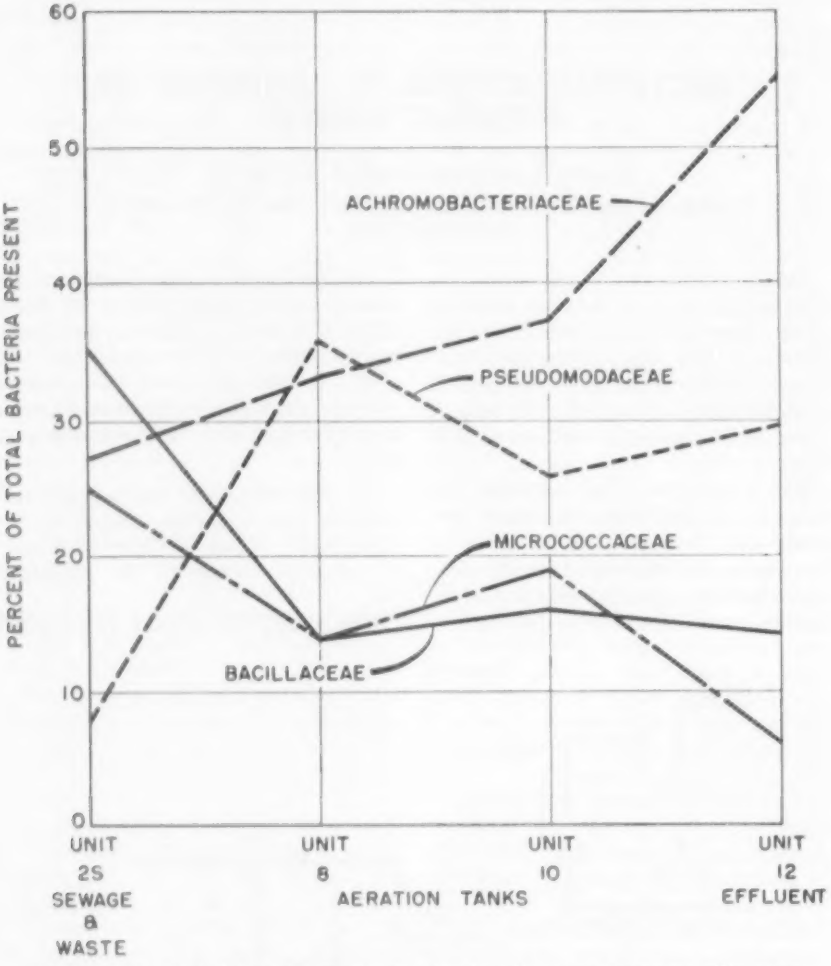

FIGURE 2.—Bacterial family distribution in phenolic waste treatment pilot plant.

of a settling tank for raw sanitary sewage (Unit 8), a mixing tank for sewage and strong phenolic wastes (Unit 2S), suspended media aeration tanks (Units 8 and 10) in series, and a final settling tank (Unit 12). The aeration units were the so-called Emscher filters, designed after Bach's early work in the Emscher Valley of Germany on by-product coke oven wastes. At the time of the sampling for bacterial identification, the sewage flow was 0.75 g.p.m., the phenolic waste flow was 0.50 g.p.m., and the performance of the units was as follows:

Unit	Phenol (p.p.m.)	D.O. (p.p.m.)	B.O.D. (p.p.m.)
2S	7.0	0.6	193
8	0.16	3.2	112
10	0.16	—	—
12	0.28	2.4	52

On August 11, 1936, samples were taken from the units 2S, 8, 10, and 12. Samples 8 and 10 were taken from the aeration tank overflow weir boxes. It was considered that 30 or more isolates chosen at random from each of the units would give a good picture of the flora dominating in that particular unit. This work was done with the intention of definitely establishing the taxonomy of the flora as far as genera. It is probable that individual species will vary over a period of time, according to the character of the incoming sewage. Thus, in most instances, the species identification is given merely to establish the genus under which the particular organism falls. Therefore, this paper should not be misconstrued to mean that any of the particular species herein named will dominate at any given time. However, the families and genera listed should correspond fairly well to the flora in the designated units when conditions are similar to those existing at the time these samples were taken.

The organisms are listed (Tables I,

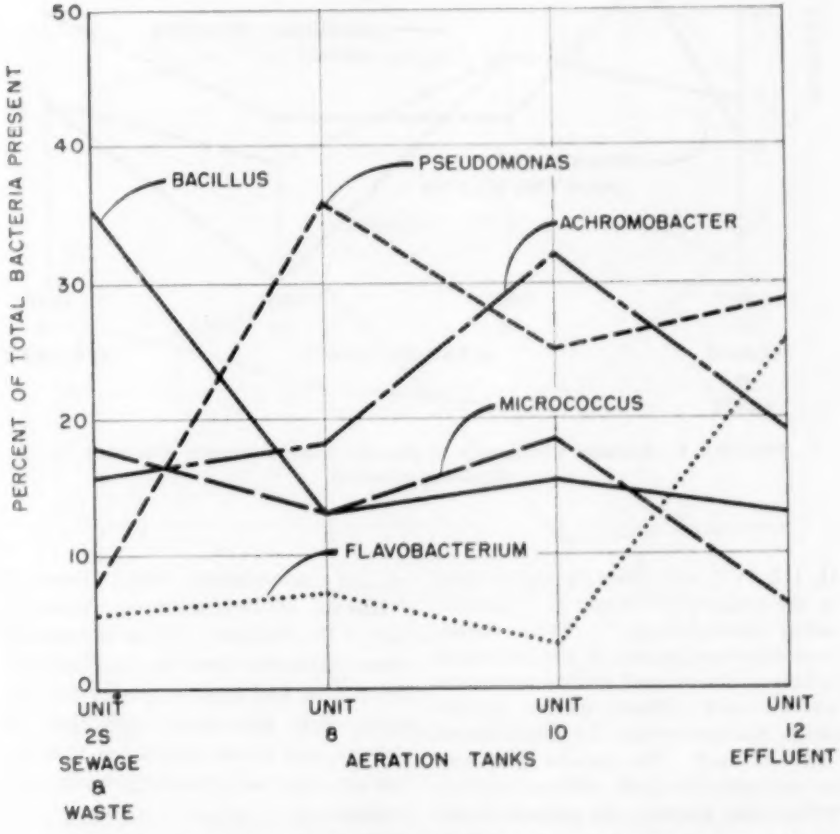

FIGURE 3.—Bacterial genus distribution in phenolic waste treatment pilot plant.

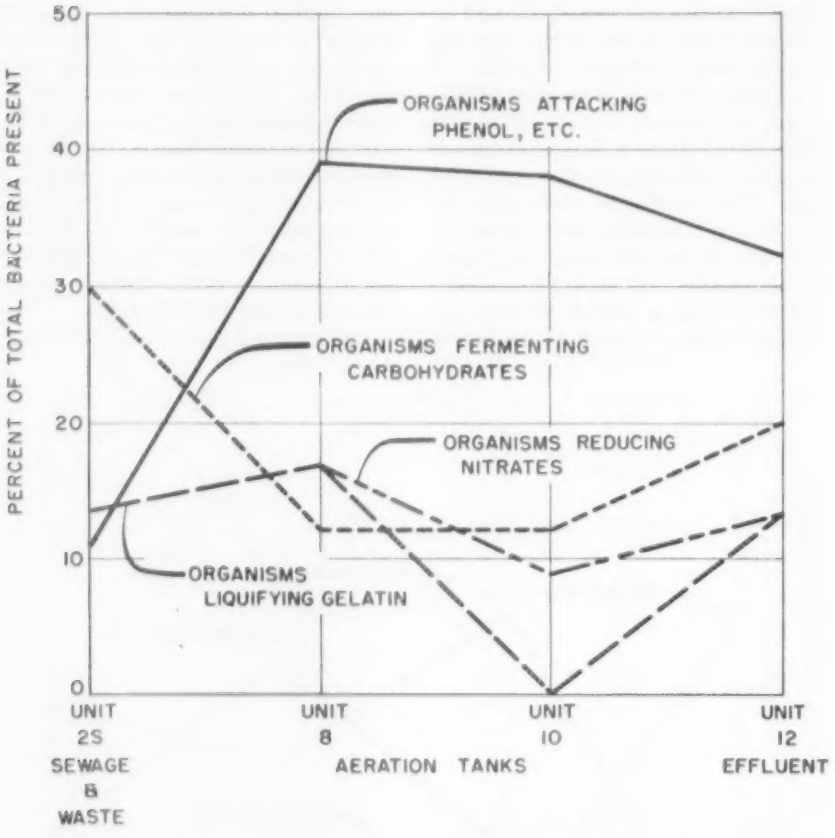

FIGURE 4.—Bacterial distribution in phenolic waste treatment pilot plant by physiological action.

II, III, IV), with their characteristics, in the manner of Bergey's "Determinative Bacteriology." Those organisms which are known in the literature to attack phenol and similar aromatics are indicated. Where species identification was not certain the abbreviation "sp." is used. The species sub-number indicates distinctly different species within the genus. All nomenclature is in accordance with Bergey's "Manual of Determinative Bacteriology," 6th Edition. These determinations indicated that the predominant microflora had their origin in the soil water that was mixed with the raw sewage, and it was concluded that the sewage was not necessary to the operation.

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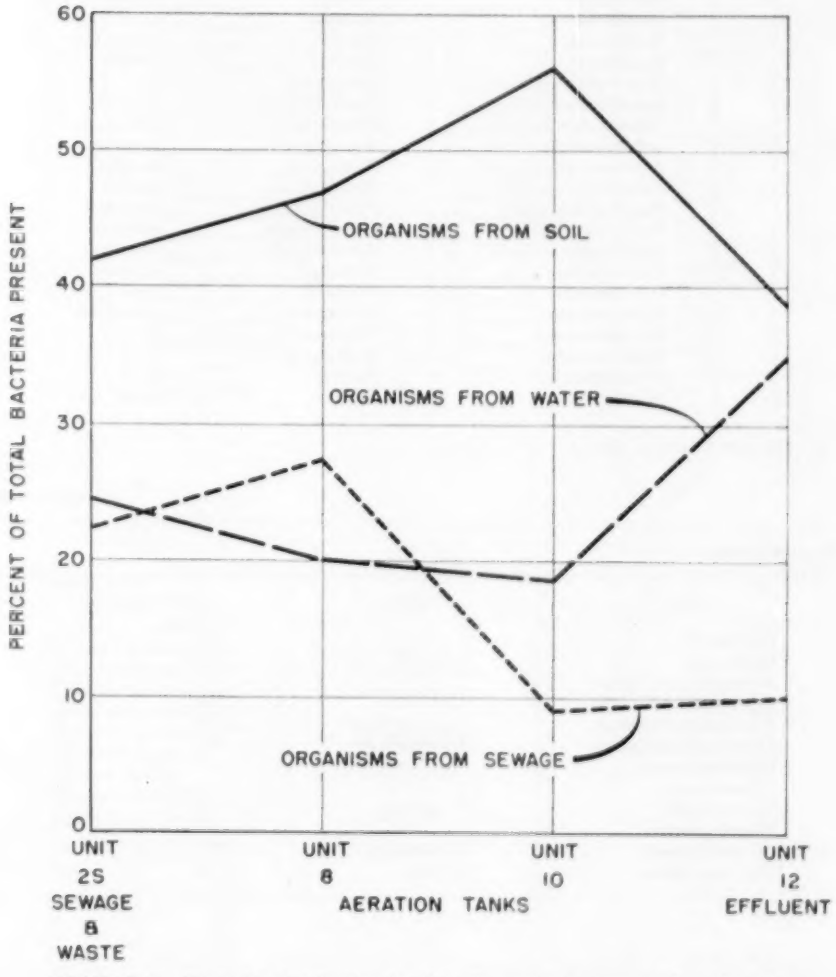

FIGURE 5.—Bacterial distribution in phenolic waste treatment pilot plant by normal habitat.

TABLE I.—Summary of Organisms Found in Unit 2S (See also Figures 2, 3, and 4)

No. of Isolates	Family	Genus	Species
6	Bacillaceae	*Bacillus*	sp. 1
2	Bacillaceae	*Bacillus*	sp. 2
2	Bacillaceae	*Bacillus*	*pseudotetanicus*
1	Bacillaceae	*Bacillus*	sp. 3
1	Bacillaceae	*Bacillus*	*sphaericus*
1	Bacillaceae	*Bacillus*	*subtilis*
1	Achromobacteriaceae	*Alcaligenes*	sp. 1
1	Achromobacteriaceae	*Flavobacterium*	sp. 1
1	Achromobacteriaceae	*Flavobacterium*	*matizoonii*
5	Achromobacteriaceae	*Achromobacter*	*guttatum*
1	Achromobacteriaceae	*Alcaligenes*	*faecalis*
1	Pseudomonadaceae	*Pseudomonas*	*turcosa*
1	Pseudomonadaceae	*Pseudomonas*	*caudata*
1	Pseudomonadaceae	*Pseudomonas*	*nebulosa*
1	Achromobacteriaceae	*Achromobacter*	*revenilii*
1	Neisseriaceae	*Neisseria*	*subflava*
1	Neisseriaceae	*Neisseria*	*flava*
4	Micrococcaceae	*Micrococcus*	*piltonensis*[1]
2	Micrococcaceae	*Micrococcus*	sp. 1
1	Micrococcaceae	*Micrococcus*	sp. 2
1	Micrococcaceae	*Sarcina*	sp. 1
1	Micrococcaceae	*Sarcina*	*ureae*

[1] Known to attack phenol.

Recapitulation

Family	Genus	Percentage of Total	
Bacillaceae	—	—	35.2
Bacillaceae	*Bacillus*	35.2	—
Achromobacteriaceae	—	—	27.0
Achromobacteriaceae	*Alcaligenes*	5.4	—
Achromobacteriaceae	*Flavobacterium*	5.4	—
Achromobacteriaceae	*Achromobacter*	16.2	—
Pseudomodaceae	*Pseudomonas*	—	8.1
Neisseriaceae	—	—	5.4
Neisseriaceae	*Neisseria*	5.4	—
Micrococcaceae	—	—	24.2
Micrococcaceae	*Micrococcus*	18.8	—
Micrococcaceae	*Sarcina*	5.4	—

TABLE II.—Summary of Organisms Found in Unit 8 (See also Figures 2, 3, and 4)

No. of Isolates	Family	Genus	Species
1	Bacillaceae	*Bacillus*	sp. 1
1	Bacillaceae	*Bacillus*	*circulans*[1]
1	Bacillaceae q	*Bacillus*	*pumilus*
2	Bacillaceae	*Bacillus*	sp. 3
11	Pseudomonadaceae	*Pseudomonas*	*cruciviae*[1]
1	Pseudomonadaceae	*Pseudomonas*	*nebulosa*
2	Pseudomonadaceae	*Pseudomonas*	*dacunhae*[1]
1	Achromobacteriaceae	*Achromobacter*	sp. 1
1	Achromobacteriaceae	*Achromobacter*	sp. 2
2	Achromobacteriaceae	*Achromobacter*	*superficiale*
1	Achromobacteriaceae	*Achromobacter*	sp. 3
1	Achromobacteriaceae	*Achromobacter*	sp. 4
1	Achromobacteriaceae	*Achromobacter*	sp. 5
3	Achromobacteriaceae	*Flavobacterium*	sp. 1
3	Achromobacteriaceae	*Alcaligenes*	*faecalis*
1	Enterobacteriaceae	*Escherichia*	*gastrica*
1	Enterobacteriaceae	*Escherichia*	*anindolica*
2	Micrococcaceae	*Micrococcus*	sp. 3
1	Micrococcaceae	*Micrococcus*	sp. 4
2	Micrococcaceae	*Micrococcus*	sp. 5

[1] Known to attack phenol.

Recapitulation

Family	Genus	Percentage of Total	
Bacilliaceae	—	—	12.8
Bacilliaceae	*Bacillus*	12.8	—
Achromobacteriaceae	—	—	33.3
Achromobacteriaceae	*Alcaligenes*	7.7	—
Achromobacteriaceae	*Flavobacterium*	7.7	—
Achromobacteriaceae	*Achromobacter*	17.9	—
Pseudomonodaceae	—	—	36.0
Pseudomonodaceae	*Pseudomonas*	36	—
Micrococcaceae	—	—	12.8
Micrococcaceae	*Micrococcus*	12.8	—
Enterobacteriaceae	—	—	5.1
Enterobacteriaceae	*Escherichia*	5.1	—

TABLE III.—Summary of Organisms Found in Unit 10 (See also Figures 2, 3, and 4)

No. of Isolates	Family	Genus	Species
4	Bacillaceae	*Bacillus*	sp. 1
1	Bacillaceae	*Bacillus*	*sphaericus*
8	Pseudomonadaceae	*Pseudomonas*	*cruciviae*[1]
2	Achromobacteriaceae	*Achromobacter*	*guttatum*
2	Achromobacteriaceae	*Achromobacter*	sp. 6
2	Achromobacteriaceae	*Achromobacter*	sp. 7
2	Achromobacteriaceae	*Achromobacter*	sp. 1
1	Achromobacteriaceae	*Achromobacter*	*superficiale*
1	Achromobacteriaceae	*Achromobacter*	sp. 2
1	Achromobacteriaceae	*Flavobacterium*	sp. 2
1	Achromobacteriaceae	*Alcaligenes*	*faecalis*
4	Micrococcaceae	*Micrococcus*	sp. 5
1	Micrococcaceae	*Micrococcus*	sp. 4
1	Micrococcaceae	*Micrococcus*	sp. 6
1	Lactobacteriaceae	*Streptococcus*	sp. 1

[1] Known to attack phenol.

Recapitulation

Family	Genus	Percentage of Total	
Bacillaceae	—	—	15.6
Bacillaceae	*Bacillus*	15.6	—
Achromobacteriaceae	—	—	37.5
Achromobacteriaceae	*Achromobacter*	31.3	—
Achromobacteriaceae	*Flavobacterium*	3.1	—
Achromobacteriaceae	*Alcaligenes*	3.1	—
Pseudomonadaceae	*Pseudomonas*	—	25.0
Micrococcaceae	—	—	18.7
Micrococcaceae	*Micrococcus*	18.7	—
Lactobacteriaceae	—	—	3.1
Lactobacteriaceae	*Streptococcus*	3.1	—

TABLE IV.—Summary of Organisms Found in Unit 12 (See also Figures 2, 3, and 4)

No. of Isolates	Family	Genus	Species
2	Bacillaceae	*Bacillus*	sp. 4
1	Bacillaceae	*Bacillus*	sp. 5
1	Bacillaceae	*Bacillus*	sp. 1
9	Pseudomonadaceae	*Pseudomonas*	*cruciviae*[1]
1	Achromobacteriaceae	*Achromobacter*	sp. 7
3	Achromobacteriaceae	*Achromobacter*	sp. 6
2	Achromobacteriaceae	*Achromobacter*	sp. 8
7	Achromobacteriaceae	*Flavobacterium*	sp. 1
1	Achromobacteriaceae	*Flavobacterium*	sp. 3
1	Enterobacteriaceae	*Escherichia*	*coli*
1	Enterobacteriaceae	*Serratia*	sp. 1
1	Micrococcaceae	*Micrococcus*	sp. 5
1	Micrococcaceae	*Micrococcus*	sp. 7

[1] Known to attack phenol.

Recapitulation

Family	Genus	Percentage of Total	
Bacillaceae	—	—	12.9
Bacillaceae	*Bacillus*	12.9	—
Pseudomonadaceae	—	—	29.0
Pseudomonadaceae	*Pseudomonas*	29.0	—
Achromobacteriaceae	—	—	45.2
Achromobacteriaceae	*Achromobacter*	19.4	—
Achromobacteriaceae	*Flavobacterium*	25.8	—
Enterobacteriaceae	—	—	6.4
Enterobacteriaceae	*Escherichia*	3.2	—
Enterobacteriaceae	*Serratia*	3.2	—
Micrococcaceae	—	—	6.4
Micrococcaceae	*Micrococcus*	6.4	—

TABLE V.—General Summary of Bacteria in Phenol Waste Pilot Plant (See also Figure 5)

Item	Unit			
	28	8	10	12
Bacteria liquefying gelatin (%)	13.5	17.5	0.0	12.9
Bacteria reducing NO_3 to NO_2 (%)	—	17.5	9.4	12.9
Bacteria fermenting carbohydrates (%)	29.7	12.5	12.5	19.3
Bacteria known to attack phenol (%)	10.8	39.0	38.5	32.0
pH of original sample	7.51	7.53	7.53	7.49
Bacteria in original sample (10^6/ml.)	14	1.6	2.5	1.1

STUDIES OF BIOCHEMICAL OXIDATION BY DIRECT METHODS

IV. Effect of Toxic Metal Ions on Oxidation *

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The toxicity of metal ions on biochemical treatment processes is important from the standpoint of separate or combined treatment of industrial wastes, as evidenced by the special review of the literature on toxic materials by the Research Committee in 1950 (4). This review compiled the information pertaining to toxicity of organic and inorganic wastes on aerobic and anaerobic treatment processes, on self-purification of streams, on the microflora and microfauna of streams, and on the B.O.D. test. In all, 177 references were included under these various headings. Additional information has been forthcoming since the publication of that report.

It is the purpose of the present paper to furnish additional information regarding the toxicity of metal ions on the oxidation of sewage and activated sludge-sewage mixtures and to determine the influence of a number of variables, such as effect of pH and the concentration of sewage on these phenomena.

The development of additional tools of research, such as the manometric methods, since the review of the literature has facilitated greatly the study of this problem. Manometric methods have been used successfully by the senior author (3) and Dawson and Jenkins (1) for this purpose.

Determination of Metal Ion Toxicity

The following procedure was used to determine the toxicity of several metal ions in domestic sewage. The metals used included copper, nickel, zinc, cadmium, trivalent chromium, hexavalent chromium, and cobalt. For this purpose stock solutions of copper sulfate, nickel chloride, zinc chloride, cadmium sulfate, chromium nitrate, potassium chromate, and cobalt chloride were prepared. Each contained 1 mg. per ml. concentration of the particular metal ion. Domestic sewage was obtained and filtered through cotton to provide a more homogeneous sewage. Samples were prepared that contained 90 ml. of sewage, sufficient stock solution to provide the desired metal concentration, and distilled water to make a final volume of 100 ml. An aliquot portion was placed in the Warburg apparatus for measurement of oxygen utilization at 20° C. over a 5-day period. The range of metal ion concentrations studied included from 1 to 100 p.p.m., and in each case the oxygen utilization of a control sewage sample was measured for purposes of comparison. Initial pH measurements were made to determine whether addition of the reagents (stock metal ion solutions) had altered the pH to such an extent as to affect the oxygen utilization of the sewage sample. The 5-day B.O.D. of the cotton filtered sewage used varied from 200 to 280 p.p.m. during these studies. The results obtained are presented in tabular form, indicating the percentage of the control 5-day B.O.D. exerted at a given time interval.

Results

Addition of 1 p.p.m. copper produced a significant reduction in per-

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TABLE I.—Effect of Copper Concentration on Biochemical Oxidation[1] of Domestic Sewage

Time (days)	Copper Concentration (p.p.m.)						
	0	1	2.5	5	10	25	50
1	59	54	39	6	3	3	5
1.25	65	59	54	33	10	4	5
2	85	64	62	57	51	33	5
3	96	70	67	64	61	56	5
4	98	75	70	66	64	62	5
5	100	78	72	68	66	66	5

[1] Expressed as percentage of control 5-day B.O.D.

centage of control oxygen demand exerted (Table I). With 2.5 p.p.m. a further reduction, particularly of the 1-day oxygen demand, was effected. Addition of 5 p.p.m. produced a 1-day lag period, which was increased to 2 days at 10 and 25 p.p.m. copper. At 50 p.p.m. complete inhibition of biochemical oxidation resulted and no recovery was evident during the 5-day observation period. Where marked initial toxic effects were observed with 5 to 25 p.p.m. copper, a similar degree of recovery resulted, in that after 5 days from 66 to 68 per cent of the control oxygen utilization had been exerted.

Addition of 5 p.p.m. nickel produced a marked initial retardation with a 1-day lag period (Table II). With 10 p.p.m. nickel a 1.25-day lag period resulted before the initial toxic effect was partially overcome. After 5 days both samples had recovered to such an extent that 76 and 68 per cent of the control oxygen utilization had been exerted. Addition of 25 and 50 p.p.m. nickel produced greater than 90 per cent inhibition, and no recovery was evident during the 5-day period.

Small but significant reductions in oxygen utilization occurred upon the addition of 5 and 10 p.p.m. zinc to sewage (Table III). With 25 p.p.m. a further decrease was observed. Addition of 50 p.p.m. caused a 1-day lag period, which was increased to 1.25 days by addition of 75 and 100 p.p.m. zinc. Recovery from the initial toxic effects was obtained at all added zinc concentrations; therefore, at 100 p.p.m. zinc 60 per cent of the control oxygen utilization was obtained in 5 days.

Addition of 5 p.p.m. cadmium resulted in a small but significant reduction in oxygen utilization (Table IV). This reduction was still greater with 10 p.p.m. cadmium. A 1-day lag period was obtained at 25 p.p.m., while addition of 50 p.p.m. caused a 2-day lag period. Addition of 75 p.p.m. produced an inhibition of oxygen utilization greater than 90 per cent for the entire 5-day period. Recovery from initial toxic effects caused by 10 to 50 p.p.m. cadmium was obtained, so that the 5-day oxygen demand was from 78

TABLE II.—Effect of Nickel Concentration on Biochemical Oxidation[1] of Domestic Sewage

Time (days)	Nickel Concentration (p.p.m.)				
	0	5	10	25	50
1	57	8	8	8	5
1.25	63	23	11	8	5
2	80	62	48	8	5
3	90	70	61	8	5
4	96	74	65	8	5
5	100	76	68	8	5

[1] Expressed as percentage of control 5-day B.O.D.

TABLE III.—Effect of Zinc Concentration on Biochemical Oxidation[1] of Domestic Sewage

Time (days)	Zinc Concentration (p.p.m.)						
	0	5	10	25	50	75	100
1	59	50	45	33	8	5	5
1.25	65	58	58	51	35	12	6
2	85	66	67	60	53	46	29
3	96	77	77	67	61	57	49
4	98	85	85	73	68	63	56
5	100	88	88	76	72	65	60

[1] Expressed as percentage of control 5-day B.O.D.

TABLE IV.—Effect of Cadmium Concentration on Biochemical Oxidation[1] of Domestic Sewage

Time (days)	Cadmium Concentration (p.p.m.)					
	0	5	10	25	50	75
1	57	46	32	8	4	4
1.25	63	56	51	31	4	4
2	80	63	61	58	4	4
3	90	70	67	68	22	4
4	96	77	73	66	48	6
5	100	84	78	67	61	8

[1] Expressed as percentage of control 5-day B.O.D.

to 61 per cent, respectively, of the control oxygen utilization.

Concentrations up to 10 p.p.m. of trivalent chromium produced little effect on oxygen utilization, while 25 p.p.m. resulted in a considerable reduction initially which was overcome as the time interval increased (Table V). Similar results were obtained with 50 p.p.m. chromium, differing only in that the recovery was more gradual. Addition of 75 p.p.m. chromium allowed some initial oxygen utilization but complete inhibition beyond the first day. At this concentration, inhibition of oxygen utilization was 82 per cent for the 5-day period.

The effect of increasing concentrations of hexavalent chromium on oxygen utilization of sewage is a gradual one, and a concentration of 100 p.p.m.

TABLE V.—Effect of Trivalent Chromium Concentration on Biochemical Oxidation[1] of Domestic Sewage

Time (days)	Trivalent Chromium Concentration (p.p.m.)				
	0	10	25	50	75
1	56	55	20	18	18
2	82	81	47	34	18
3	92	90	72	58	18
4	97	97	81	67	18
5	100	100	86	73	18

[1] Expressed as percentage of control 5-day B.O.D.

TABLE VI.—Effect of Hexavalent Chromium Concentration on Biochemical Oxidation[1] of Sewage

Time (days)	Hexavalent Chromium Concentration (p.p.m.)					
	0	10	25	50	75	100
0.75	47	40	32	26	18	12
1	55	49	50	43	39	34
2	79	68	62	56	56	56
3	87	81	67	61	61	61
4	94	90	81	71	65	64
5	100	97	90	85	70	67

[1] Expressed as percentage of control 5-day B.O.D.

is not sufficient to exert a complete toxic effect (greater than 90 per cent inhibition) (Table VI). At 100 p.p.m. a 0.75-day lag period is observed, but this is overcome rapidly so that after 1 day 34 per cent of the control 5-day oxygen utilization has been exerted. After 5 days the oxygen utilization is 67 per cent of the control sample.

Addition of 5 p.p.m. cobalt produces a marked initial retarding effect which is gradually reduced with increased time (Table VII). Even greater initial retardation is obtained with 10 p.p.m., and at 25 p.p.m. a 2-day lag period is observed. After 5 days 50 per cent of the control oxygen utilization was exerted. Addition of 50 p.p.m. cobalt causes complete inhibition of oxygen utilization (greater than 90 per cent).

TABLE VII.—Effect of Cobalt Concentration on Biochemical Oxidation[1] of Sewage at Varying Time Intervals

Time (days)	Cobalt Concentration (p.p.m.)				
	0	5	10	25	50
0.75	48	18	8	4	5
1	56	30	17	5	5
2	80	56	47	8	6
3	89	64	56	25	5
4	95	70	60	42	5
5	100	76	64	50	6

[1] Expressed as percentage of control 5-day B.O.D.

TABLE VIII.—Determination of Added Metal Ion Concentration[1] Required to Produce 10, 50, and 90 Per Cent Reduction of Biochemical Oxidation of Domestic Sewage at 1- and 5-Day Intervals

Metal Ion Added	Reduction of Biochemical Oxidation (%)					
	10 Per Cent		50 Per Cent		90 Per Cent	
	1-Day	5-Day	1-Day	5-Day	1-Day	5-Day
Copper	1	1	3	35	5	45
Nickel	1	1	3	15	5	25
Zinc	3	3	30	62.5	60	100
Cadmium	3	3	10	55	35	75
Trivalent Cr	12.5	20	17.5	62.5	100	100
Hexavalent Cr	10	25	100	100	100	100
Cobalt	1	1	5	25	20	42.5

[1] Results given as p.p.m. metal ion concentration.

In Table VIII, data from previous tables are compiled showing the percentage retardation of control oxygen utilization after 1 and 5 days. Using the data for 1 day, the order of decreasing metal toxicity was nickel, copper, cobalt, cadmium, zinc, trivalent chromium, and hexavalent chromium. Using the 5-day data, the order of toxicity is changed somewhat so that the picture is as follows: nickel, copper, cobalt, cadmium, trivalent chromium, zinc, hexavalent chromium. In each case the concentration of added metal ion needed to obtain a particular degree of retardation of oxidation is increased as the time interval is increased. Taking the data for nickel as an example, 3 p.p.m. were sufficient to cause 50 per cent reduction of oxygen utilization for 1 day, whereas 15 p.p.m. were needed for the same degree of retardation after 5 days.

In order to illustrate that it is possible to develop a flora capable of oxidizing sewage in the presence of increasing higher added concentrations of toxic metal ions, the following experiment is given. Concentrations of 25 and 75 p.p.m. of copper and trivalent chromium were added to each of four sewage samples and the oxidation rates determined in the Warburg apparatus for a 5-day period. New samples containing the same added metal concentrations were then prepared and seeded with 25 per cent by volume of the respective samples in the

TABLE IX.—Effect of Adaptation of Seed on the Toxicity of Trivalent Chromium and Copper Added to Sewage[1]

Sample	Days				
	1	2	3	4	5
Control	54	76	88	95	100
Chromium 25 p.p.m., 1st passage	19	49	62	69	74
Chromium 25 p.p.m., 2nd passage	44	65	71	78	83
Chromium 75 p.p.m., 1st passage	12	45	56	64	80
Chromium 75 p.p.m., 2nd passage	49	73	81	86	92
Copper 25 p.p.m., 1st passage	15	56	63	67	71
Copper 25 p.p.m., 2nd passage	56	93	95	96	98
Copper 75 p.p.m., 1st passage	13	12	13	12	14
Copper 75 p.p.m., 2nd passage	18	18	18	30	63

[1] Expressed as percentage of control 5-day B.O.D. exerted.

first passage (the 75-p.p.m. metal sample for the second passage being seeded from the 25-p.p.m. metal sample of the first passage). The new samples were similarly incubated in the Warburg apparatus for 5 days. The results (Table IX) are compared with those of the first passage to determine whether any increase in oxidation (decrease in toxicity) occurred. The results show that on the second passage higher oxidation rates were obtained with each metal concentration. In the case of 25 p.p.m. copper some stimulatory effect was observed as indicated by a rate of oxidation higher than that of the control upon the second passage.

Effect of Peptone Addition on Toxicity of Cobalt

To determine the effect of an increase in organic matter concentration in sewage on the toxicity resulting from several cobalt additions, peptone was added in varying concentrations.

Using a relatively weak cotton-filtered domestic sewage, three "sewages" were prepared, as follows:

1. Sewage alone.
2. Sewage plus 150 p.p.m. peptone.
3. Sewage plus 300 p.p.m. peptone.

Using each sewage, three samples were prepared containing 0, 10, and 25 p.p.m. cobalt; aliquot portions of all nine samples were placed in a Warburg apparatus for measurement of oxygen utilization at 20° C over a 5-day period.

The results (Table X) show that addition of peptone did not decrease the toxicity of the concentrations of cobalt employed. While the total oxygen utilization at 10 p.p.m. cobalt addition increases as the peptone concentration increases (52 p.p.m. with sewage alone, compared to 105 p.p.m. with sewage plus 300 p.p.m. peptone), actually the percentage of the control oxygen demand exerted in 5 days decreases. In general, the toxic effect produced by each cobalt concentration remains unaltered; namely 10 p.p.m. produces a partial degree of inhibition, while 25 p.p.m. causes greater than 90 per cent or complete inhibition of oxygen utilization during the 5-day period.

Effect of Sewage Concentration on Metal Ion Toxicity

Several experiments were carried out to determine whether the strength or concentration of sewage used was a factor affecting the degree of inhibition produced by a particular added metal ion concentration.

Using cotton-filtered domestic sewage with 300 p.p.m. 5-day B.O.D., three sewage samples were prepared containing 100, 50 and 25 per cent sewage by volume. Using each sewage concentration, three samples were prepared containing 25, 50, and 75 p.p.m., respectively, of trivalent chromium. The same procedure was followed using a sewage with 455 p.p.m. B.O.D. and copper concentration of 25, 50, and 75

TABLE X.—Effect of Addition of Varying Quantities of Peptone on Toxicity[1] of Several Concentrations of Cobalt in Domestic Sewage

Time (days)	Sewage Alone			Sewage +150 P.P.M. Peptone			Sewage +300 P.P.M. Peptone		
	0	10	25	0	10	25	0	10	25
1	53	9	5	104	7	9	134	14	9
2	84	26	5	174	39	9	264	77	12
3	89	42	7	192	65	9	298	88	10
4	95	51	9	199	70	9	319	96	10
5	98	52	12	215	72	7	335	105	10

[1] Results expressed as p.p.m. oxygen utilized.

TABLE XI.—Effect of Sewage Concentration on Toxicity of Trivalent Chromium and Copper [1]

Time (days)	Sewage Concentration (%)									
	100				50			25		
	Added Metal Concentration (p.p.m.)									
	0	25	50	75	25	50	75	25	50	75
	(*a*) Chromium									
1	57	31	10	5	3	4	4	1	1	1
2	81	51	34	28	20	13	3	3	3	3
3	92	61	46	34	34	28	3	4	4	3
4	96	67	52	41	40	33	3	12	4	4
5	100	73	56	45	47	37	3	24	3	5
	(*b*) Copper									
1	56	7	4	4	3	3	3	3	4	3
2	82	52	48	5	45	4	4	3	4	3
3	91	58	57	42	55	4	4	3	4	3
4	95	60	59	54	58	4	4	3	4	3
5	100	63	63	61	61	5	11	11	4	3

[1] Expressed as percentage of control 5-day B.O.D. exerted.

p.p.m. The pH of all samples was adjusted to 6.5 and aliquot portions were placed in a Warburg apparatus for measurement of oxygen utilization at 20° C. for 5 days. The results obtained, corrected for concentration of sewage employed, and expressed as percentage of 5-day control B.O.D. exerted at a given time interval, are given in Table XI, which shows that at 100 per cent sewage concentration none of the chromium concentrations produced 90 per cent inhibition, although as the concentration was increased from 25 to 75 p.p.m. the inhibition of 5-day B.O.D. increased from 25 to 55 per cent. When the sewage concentration was decreased to 50 per cent, the toxic effect of each chromium concentration was greatly increased, and 75 p.p.m. produced greater than 90 per cent inhibition. At 25 per cent sewage concentration the toxicity of the three chromium concentrations was increased still further, and 50 p.p.m. was sufficient to produce greater than 90 per cent inhibition of 5-day B.O.D.

The results obtained when copper was used show a similar trend. At 100 per cent sewage none of the copper dosages produced 90 per cent inhibition, although an increase in copper concentration from 50 to 75 p.p.m. lengthened the lag period from 1 to 2 days. With 50 per cent sewage, however, 90 per cent inhibition was obtained with both 50 and 75 p.p.m. copper. With 25 per cent sewage there was a marked increase in toxicity of 25 p.p.m. copper, resulting in 90 per cent inhibition of 5-day B.O.D.

To determine whether a proportionate decrease in both sewage and added metal concentration resulted in the same toxic effect, the following experiment was conducted. Samples of cotton-filtered sewage were prepared containing sewage concentrations of 100, 50, and 25 per cent. Two concentrations of each of two metal ions (copper and cobalt) were studied at each sewage concentration. At 100 per cent sewage, 80 and 20 p.p.m. cobalt or copper were used; with 50 per cent

sewage, 40 and 10 p.p.m.; and at 25 per cent concentration, 20 and 5 p.p.m. The results (Table XII) are expressed as cumulative percentage of control 5-day oxygen utilization, with all values corrected for variation in sewage concentration.

The results obtained in the 80–40–20–p.p.m. cobalt series show a slight decrease in toxic effect as the sewage-metal concentration is decreased. All three samples showed at least a 2-day lag period before oxidation began, and all levelled off at around 50 per cent of 5-day control oxygen demand. In the 20–10–5-p.p.m. cobalt series a uniform toxic effect was observed in each sample (namely, a 1-day lag period and a levelling off of oxygen utilization at 67 per cent of 5-day control oxygen demand). The 80–40–20-p.p.m. copper series gave uniform results, almost complete inhibition of oxygen utilization being observed in all three samples. Again, in the 20–10–5-p.p.m. copper series uniform results were obtained (namely a 1-day lag period and a levelling off of oxygen utilization at 63 per cent of the 5-day control oxygen demand).

TABLE XII.—Effect of Proportionate Dilution of Sewage and Cobalt and Copper Concentration on Toxic Effect Produced[1]

Time (days)	Sewage Concentration (%)						
	100	100	50	25	100	50	25
		Metal Ion Concentration (p.p.m.)					
	0[2]	80	40	20	20	10	5
	(*a*) Cobalt						
1	49	3	3	1	6	8	11
2	77	4	4	4	38	42	45
3	90	5	12	25	54	54	56
4	94	12	38	38	59	59	60
5	100	45	50	50	65	65	69
	(*b*) Copper						
1	49	11	9	10	5	5	4
2	77	11	9	10	38	40	38
3	90	11	10	10	51	51	52
4	94	11	10	10	55	57	56
5	100	14	12	12	60	63	63

[1] Expressed as percentage of control 5-day B.O.D. exerted.
[2] Control.

Effect of pH on Metal Ion Toxicity

Another factor studied to determine its effect on metal ion toxicity in sewage was pH. It is well known that the solubility of metal ions is affected by pH. It is, therefore, conceivable that toxic effects produced by these ions would be affected by the pH of the substrate.

A study was made of the effect of initial pH of sewage on the toxicity of several concentrations each of copper and trivalent chromium. Each metal was studied at two concentrations: copper at 25 and 50 p.p.m., and trivalent chromium at 25 and 75 p.p.m. The specified metal ion concentration was added to samples of cotton-filtered sewage and the initial pH adjusted to values of 5, 6, 7, and 8. The toxic effects produced were evaluated by measuring oxygen utilization of aliquot samples over a 5-day period at 20° C. in a Warburg apparatus. The effect of initial pH in the absence of toxic metals was determined for the same pH range. Decrease in pH to 5 had no effect on the oxygen demand of the control sewage other than to cause a small initial stimulation of oxygen utilization. The results are expressed as cumulative percentage of 5-day control oxygen demand exerted at different time intervals.

The results obtained with copper (Table XIII) show that as the initial pH is increased from 5 to 8, the toxic effect produced by either 25 or 50 p.p.m. added copper ion is decreased. Thus, in the 25-p.p.m. series, there is a 5-day lag period at pH 5, a 2-day lag period at pH 6, and a 1-day lag period at pH 7 and 8 before oxidation of the sewage begins. In the 50-p.p.m. series,

TABLE XIII.—Effect of Initial pH on Toxicity[1] of 25 and 50 P.P.M. Copper Added to Domestic Sewage[2]

Time (days)	Control		25 P.P.M. Copper				50 P.P.M. Copper			
	pH 5	pH 7	pH 5	pH 6	pH 7	pH 8	pH 5	pH 6	pH 7	pH 8
1	60	55	7	5	2	1	7	4	2	1
2	83	75	7	14	40	44	7	6	4	10
3	95	89	7	38	56	55	8	30	28	47
4	101	96	8	54	60	58	8	41	45	55
5	105	100	16	60	62	60	8	52	53	59
6	109	103	42	65	65	63	8	59	59	61

[1] Expressed as percentage of 5-day control oxygen demand exerted.
[2] With 5-day B.O.D. of 245 p.p.m.

the toxic effects produced at each pH are all greater, but the same trend is evident. At pH 5, complete inhibition (greater than 90 per cent reduction of oxygen demand) was obtained over the 6-day period. At pH 6 the lag period was of 2-day duration, similar results being obtained at pH 7 and 8. In both series a slight initial stimulatory effect was observed at the lower pH values 5 and 6, equal to the difference in 1-day oxygen demand of the control samples at pH 5 and 7. This indicates that the effect is of a chemical nature and caused by the lowered pH. The critical pH range over which there was a marked change in effectiveness of a given copper dosage fell between 5 and 6.5 in both series of experiments. Where the lag period was overcome the oxygen demand curves levelled off at about 60 per cent of the 5-day control oxygen demand.

The results obtained with trivalent chromium (Table XIV) follow a similar pattern. In both experiments (25 and 75 p.p.m. chromium added) a critical range was observed between pH 6 and 7. Initial stimulatory effects similar to those obtained in the copper experiments were observed at pH 5 and 6. Successively shorter lag periods were observed as the pH was increased from 5 to 8 for a given concentration of chromium added. At pH 7 and 8 nearly identical oxygen demand results were obtained at each time interval over the 5-day period. In both series the oxidation curves for pH 7 and 8 samples level off after overcoming the initial lag at 75 to 80 per cent of the control 5-day oxygen demand.

To explain the variation in toxic effects produced by a given concentration of copper at different pH values, a study was made of the solubility of copper in sewage over the

TABLE XIV.—Effect of Initial pH on Toxicity[1] of 25 and 75 P.P.M. Trivalent Chromium Added to Domestic Sewage[2]

Time (days)	Control pH 7	25 P.P.M. Chromium				75 P.P.M. Chromium			
		pH 5	pH 6	pH 7	pH 8	pH 5	pH 6	pH 7	pH 8
1	54	9	0	19	30	20	14	12	10
2	76	10	16	49	52	18	13	45	43
3	88	11	20	62	66	18	13	55	58
4	95	27	23	69	73	17	12	64	65
5	100	37	25	74	78	18	13	80	71

[1] Expressed as percentage of 5-day control oxygen demand exerted.
[2] With 5-day B.O.D. of 150 p.p.m.

pH range 4 to 8. The procedure used was to add the desired copper concentration to the sewage, adjust the pH, agitate and allow to stand several minutes, and filter through No. 2 paper to produce a clear filtrate. Residual copper was determined by diluting a given sample volume to 50 ml., adding 2 ml. of 1:5 ammonia water, 1 ml. sodium diethyl-dithiocarbamate, allowing the yellow-orange color to develop and measuring the transmittancy with the electrophotometer. Two initial copper concentrations (100 and 20 p.p.m.) were used and cotton-filtered sewage was employed.

The results obtained are given in Table XV. At pH 4, all the added copper was in solution, but as the pH increased the copper remaining in solution decreased. A critical region was observed between pH 5 and 6.5, where the copper solubility dropped sharply toward a final value around 5 p.p.m. These results show that at pH 7 and 8 only a small portion of the added copper remains in solution. There is a definite correlation between the initial pH range for copper toxicity and copper solubility, suggesting that the explanation for the increased toxic effect produced by a given copper dosage at lower pH values is due to the greater solubility of copper at low pH.

TABLE XV.—Solubility of Copper in Sewage at Various pH Values

Adjusted pH	Copper Solubility (p.p.m.)	
	Init. Cu = 100 P.P.M.	Init. Cu = 20 P.P.M.
4	100	20
5	85	15
6	43	5.5
7	10	5.5
8	3	5.2

Toxicity of Metal Ions Added to Sewage Activated Sludge Mixtures

To supplement the results presented in the section dealing with the effect of seven toxic metals on biochemical oxidation of sewage, a similar series of experiments was conducted using domestic sewage-activated sludge mixed liquor as the test substrate. The metal ions used were copper, nickel, zinc, cadmium, cobalt, trivalent chromium, and hexavalent chromium. Each was studied over the concentration range from 5 to 100 p.p.m.

Return activated sludge was obtained from an activated sludge plant and maintained in the laboratory in an aeration column by feeding with screened sewage once each day and aerating at a sludge solids concentration of 2,000 p.p.m. suspended solids. After each aeration period the mixed liquor was settled and the supernatant decanted. Fresh sewage was added and the procedure was repeated. This procedure was followed for three days before the sludge was used experimentally.

Samples were prepared by drawing sludge from the aeration column, determining its approximate suspended solids concentration by centrifugation and making up the sample to contain the desired metal ion concentration, 70 per cent sewage by volume, and sufficient sludge to give a suspended solids concentration of 2,000 p.p.m. An aliquot portion was placed in a Warburg apparatus for measurement of oxygen utilization over a 24-hr. period at 20° C. The rates of oxygen utilization of control samples containing 2,000 p.p.m. sludge solids and 2,000 p.p.m. solids plus sewage were measured simultaneously in each experiment.

The sludge used in these experiments may be considered as well-oxidized, since its first-hour oxygen demand averaged 70 p.p.m. for each per cent of suspended solids. It settled readily and no difficulty was encountered in separating sludge and supernatant liquor.

The results taken as a whole (Tables XVI, XVII, XVIII, XIX, XX, XXI,

TABLE XVI.—Effect of Copper on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Copper Added (p.p.m.)				
			5	10	25	50	100
1	4	10	10	9	9	7	9
2	7	19	18	14	12	12	12
4	13	32	29	22	17	15	16
6	19	44	39	30	22	18	18
8	24	55	49	37	27	22	19
21	56	100	92	76	57	41	24

[1] Expressed as percentage of 21-hr. oxygen demand of control mixed liquor.

TABLE XVII.—Effect of Nickel on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Nickel Added (p.p.m.)				
			5	10	25	50	100
1	3	9	7	6	6	5	5
2	5	15	12	10	9	8	8
4	12	31	24	19	16	13	12
6	16	40	33	24	18	14	13
22	50	100	88	68	42	27	21

[1] Expressed as percentage of 22-hr. oxygen demand of control mixed liquor.

TABLE XVIII.—Effect of Cadmium on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Cadmium Added (p.p.m.)				
			5	10	25	50	100
1	3	9	7	7	6	5	8
2	5	15	14	13	9	7	11
4	12	31	28	26	18	13	16
6	16	40	38	37	25	17	18
22	50	100	89	86	74	55	30

[1] Expressed as percentage of 22-hr. oxygen demand of control mixed liquor.

TABLE XIX.—Effect of Trivalent Chromium on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Trivalent Chromium Added (p.p.m.)				
			5	10	25	50	100
1	3	10	9	9	11	11	9
2	6	20	17	19	19	19	13
4	8	32	29	29	30	25	15
6	12	42	38	38	36	30	17
8	15	51	47	47	43	33	19
26	42	100	91	88	74	53	26

[1] Expressed as percentage of 26-hr. oxygen demand of control mixed liquor.

and XXII) show that whatever toxic effects were produced at the higher metal ion concentrations were not immediately apparent during the first hour of aeration. In almost all cases the oxygen utilization by samples containing 100 p.p.m. of metal ion was practically equal to that of the control sample during the first hour, but as oxidation proceeded the differences became more noticeable. This trend is also shown by the data in Tables XXIII and XXIV, where a comparison of the various metals is made on the basis of the percentage exertion of control oxygen demand at 6 hr. and 1 day.

In no case was a 90 per cent suppression of the oxygen demand of the control sample obtained. The greatest degree of inhibition resulted with 100

TABLE XX.—Effect of Hexavalent Chromium on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Hexavalent Chromium Added (p.p.m.)				
			5	10	25	50	100
1	3	10	10	9	8	6	8
2	6	20	19	17	15	15	16
4	8	32	29	26	23	22	23
6	12	42	38	35	31	27	29
8	15	51	46	43	38	35	35
26	42	100	93	90	78	71	67

[1] Expressed as percentage of 26-hr. oxygen demand of control mixed liquor.

TABLE XXI.—Effect of Cobalt on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Cobalt Added (p.p.m.)				
			5	10	25	50	100
1	7	12	11	11	10	9	7
4	17	33	31	31	27	22	16
6	22	46	43	42	36	29	24
8	26	59	54	53	45	36	24
12	37	73	68	67	60	50	34
23	57	100	89	89	80	72	55

[1] Expressed as percentage of 23-hr. oxygen demand of control mixed liquor.

TABLE XXII.—Effect of Zinc on Oxidation of Activated Sludge-Sewage Mixed Liquor[1]

Time (hr.)	Sludge	Sewage plus Sludge	Zinc Added (p.p.m.)				
			5	10	25	50	100
1	7	12	11	11	11	7	7
4	17	33	33	32	27	18	12
6	22	46	45	44	36	23	14
8	26	59	57	56	45	29	17
12	37	73	72	71	61	38	23
23	57	100	96	94	81	57	38

[1] Expressed as percentage of 23-hr. oxygen demand of control mixed liquor.

TABLE XXIII.—Oxygen Demand Exerted[1] by Various Metals at Different Concentrations on Activated Sludge-Sewage Mixed Liquor

Metal Added	Added Metal Concentration (p.p.m.)				
	5	10	25	50	100
Copper	89	68	50	41	41
Nickel	83	60	45	35	32
Cadmium	95	92	63	43	45
Zinc	98	96	79	50	31
Cobalt	94	91	78	63	52
Chromium, triv.	91	91	81	72	41
Chromium, hexav.	91	83	74	65	69

[1] Expressed as percentage of 6-hr. oxygen demand in control mixed liquor.

p.p.m. of nickel; namely, 79 per cent reduction of control oxygen demand (Table XXIV). This was in contrast to previous results obtained with sewage alone, where using a 5-day period, 90 per cent inhibition of oxygen utilization was frequently obtained with samples containing less than 100 p.p.m. of added metal ion.

Using the data in Table XXIV, the following decreasing order of toxicity of metal ions added to sewage-activated sludge mixed liquors was obtained: nickel, copper, trivalent chromium, cadmium, zinc, cobalt, and hexavalent chromium. These results are similar to those obtained for sewage alone, with the exception that the positions of trivalent chromium and cobalt are reversed.

TABLE XXIV.—Oxygen Demand Exerted[1] by Various Metals at Different Concentrations on Activated Sludge-Sewage Mixtures

Metal Added	Added Metal Concentration (p.p.m.)				
	5	10	25	50	100
Copper	92	76	57	41	24
Nickel	88	68	42	27	21
Cadmium	88	85	73	55	30
Zinc	96	94	81	57	38
Cobalt	89	89	80	72	55
Chromium, triv.	90	88	74	53	26
Chromium, hexav.	93	90	78	71	67

[1] Expressed as percentage of 24-hr. oxygen demand in control mixed liquor.

Discussion of Results

Previous studies of metal toxicity in aerobic sewage treatment processes have primarily been of two types, involving either addition of known amounts of toxic metals to sewage being treated by trickling filters or activated sludge units and measuring the effect on treatment efficiency, or adding various concentrations of metal ions to diluted sewage to determine the effect on the 5-day oxygen demand by the standard dilution method.

The method used in this work has the advantage of recording the effect of metal ions on a basic phenomenon involved in aerobic sewage or waste treatment; namely, the effect on the rates and extent of oxidation of the substrate to which the metal ion has been added. In addition, certain difficulties attendant on the use of the dilution method, other than the difference in sewage concentration employed, are avoided, particularly the precipitation of added metal ion by the high concentrations of phosphate or bicarbonate buffer used in the mineralized standard dilution water, which make it difficult to translate the results to treatment conditions.

While the magnitudes of toxic effects obtained by addition of various metals to domestic sewage differ for equal metal concentrations, the results did fall into a general pattern, as follows: Low concentrations of metals produce slight initial toxic effects, which become more pronounced toward the end of the 5-day oxidation period. This decrease in total 5-day oxygen demand may be caused by removal of oxidizable material by means of chemical coagulation. As the metal ion concentration is increased there is an increase in the initial retardation of oxygen demand, which may extend over several days,

followed by a period of recovery where the rate of oxidation may be as great as that for the control sewage sample during the first day of oxidation. This is followed by a levelling off of oxidation at about 65 per cent of the 5-day control oxygen demand.

As with the lower metal concentrations, the percentage value coincides with the accepted maximum B.O.D. removal obtained by chemical coagulation; namely, 35 per cent or one-third of the B.O.D. Finally, as the metal concentration is increased still further, a point is reached where complete inhibition of sewage oxidation for the 5-day period is obtained. The results obtained with copper addition may be considered as characteristic in this respect. The characteristic shape of the oxygen demand curve at metal ion concentrations of intermediate toxicity is sigmoid, and the same description can be applied to the curve which relates 5-day oxygen demand to metal concentration if a semilogarithmic plot is used.

The results obtained indicate that the toxic effects observed are a resultant of several factors, including the following:

1. Removal of oxidizable materials from solution by chemical coagulation.
2. Reduction in bacterial numbers by chemical coagulation.
3. Direct toxic action on certain essential functions of the cells.

The differences in toxic effects produced by the various metals may be a result of the nature of the enzyme systems affected by the particular metal added.

A comparison of the extent of oxidation after 1- and 5-day incubation reflects the recovery of oxidation that is frequently observed after an initial reduction of oxygen demand.

A comparison of the magnitude of metal concentrations found to be toxic in this work with the results of other investigators is difficult, owing to the difference in methods used, and to the buffer interference encountered in the standard dilution method.

An increase in the concentration of oxidizable matter in sewage by addition of peptone did not decrease the toxicity of the metal cobalt ion, as might have been expected owing to possible interaction of the cobalt with the nitrogenous material, thus reducing the concentration of cobalt remaining to act upon the sewage microorganisms. Similar toxic effects were produced at each cobalt concentration, indicating that interaction of cobalt with the added material was of no importance in determining the resultant toxic effects.

Variation in sewage concentration had a marked effect on the toxic effect produced by a particular metal concentration. As the sewage was diluted the toxicity of the metal concentration increased. Where both the sewage and metal ion concentration were reduced in the same proportion, the same degree of retardation resulted. This indicates that the ratio between metal concentration and some characteristic of the sewage, such as alkalinity or numbers of organisms, is of prime importance in determining the resulting toxic effect. While these results were obtained working with three members of the group of metals (copper, trivalent chromium, and cobalt), they are believed to apply to the entire group.

The pH of the sewage to which the metal is added was found to be of major importance in determining the toxic effect produced. The explanation for this lies in the variation in metal ion solubility at different pH values. As the pH was increased from 4 to 8 there was a decrease in toxicity of given concentrations of copper and trivalent chromium. Each metal exhibited a specific pH range through which there was a sharp change in the toxic effect produced, and in the case of copper this range (pH 5 to 6.5) coincided with the critical range over

which there was a sharp change in copper solubility.

The range of metal concentrations used in the sewage and activated sludge experiments was selected because work by other investigators conducted under field conditions fell into the same range (5 to 100 p.p.m.), probably because these concentrations have been encountered in the field. The activated sludge results were similar in trend to those for sewage alone, in that increased metal concentrations produced increasing degrees of retardation of oxidation of the mixed liquor. The extent of retardation, however, was never as great as that obtained with sewage alone. This can be attributed to the far greater concentration of organisms and organic residues present in the sludge-sewage mixture than in the sewage. While the extent of retardation was less in the activated sludge than for sewage alone, the same general order of toxicity of the metals added was observed, as would be expected.

A significant feature of the activated sludge results, as contrasted with the sewage results, was that the degree of retardation became more pronounced as the aeration time was extended beyond the first few hours. In all cases the initial rate of oxidation of samples containing 100 p.p.m. metal was greater than that of the sludge alone, and in many cases was almost equal to that of the control sample containing sewage and activated sludge. The reason for this is the time required for the metal to be absorbed into the floc, particularly since a large part of the added metal may be precipitated by the sewage alkalinity. In addition, the absorption of metal may have to compete with the absorption of organic food materials by the sludge. Rudolfs and Zuber (5) showed that removal of metal ions, such as copper and zinc, from solution by activated sludge was dependent on the time of contact.

Comparing the results with those of Dawson and Jenkins (1) it should be noted that these authors used a 2.5-hr. period of observation, only 1,000 p.p.m. sludge solids, and no added sewage. This may explain why complete inhibition of sludge oxygen demand was obtained at metal concentrations up to 100 p.p.m. as compared to the results reported herein.

As to the practical significance of this work, the results show what may be expected when different concentrations of the particular metals are added to sewage or sewage-activated sludge mixed liquor undergoing biochemical oxidation, as well as the effect of certain factors such as sewage strength, sewage pH, and presence of activated sludge on the toxicity of particular metal concentrations. Under actual conditions considerable portions of the metal present may be precipitated by the alkalinity in the sewage, and, therefore, may never reach the aerobic treatment units, but instead may have a much greater effect on the sludge digestion process if that process is employed.

Summary and Conclusions

Effect of copper, nickel, zinc, cadmium, trivalent chromium, hexavalent chromium, and cobalt on oxidation of sewage and activated sludge-sewage mixtures was studied using the Warburg respirometer. In addition, the effect of increasing the organic matter concentration of the sewage by the addition of peptone on the toxicity of cobalt was studied. The concentration of sewage as a factor in the toxicity of trivalent chromium and copper on sewage was determined. The pH of the sewage substrate as a factor in the toxicity of copper and trivalent chromium in relation to the metal ion solubility was investigated. The results warrant the following conclusions:

1. The order of decreasing metal toxicity on the basis of the 5-day oxygen demands exerted was nickel, copper,

cobalt, cadmium, trivalent chromium, zinc, and hexavalent chromium. The order of toxicity on the basis of 1-day oxygen demand was slightly changed only in the case of zinc, which moved up into a position following cadmium.

2. With each ion studied the concentration required to obtain a particular degree of retardation of oxidation of sewage substrate was increased as the time interval was increased.

3. Toxicity of metal ions, such as trivalent chromium and copper, as indicated by oxygen consumption, is not a fixed value, but an increased tolerance is developed by adapting the seed to repeated additions of the metal ions.

4. The toxic effects produced in sewage-activated sludge mixtures, as indicated by inhibition of oxygen utilization, by the addition of various metals was less than those for comparable concentrations added to sewage alone.

5. The order of decreasing toxicity for activated sludge-sewage mixtures was nickel, copper, trivalent chromium, cadmium, zinc, cobalt, and hexavalent chromium.

6. In contrast with the effect of metals on the oxidation of sewage, in activated sludge-sewage mixture the retarding influence is after prolonged periods of oxidation rather than during the initial period.

7. The addition of peptone to sewage did not decrease the toxicity of the concentrations of cobalt employed.

8. For a given toxic metal ion concentration, a decrease in sewage strength results in increased retardation of oxygen utilization.

9. Where both sewage and metal concentrations are decreased in the same proportion, the same toxic effect is observed.

10. Initial pH values of sewage markedly effect the toxicity produced by particular concentrations of copper and trivalent chromium.

11. Toxicity of particular concentrations of copper and trivalent chromium decreases with an increase in pH values of sewage.

12. A characteristic critical pH range exists for each metal where there is a sharp change in toxicity.

13. The critical pH range for copper toxicity coincides with the pH value over which there is a sharp change in copper solubility.

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Stream Pollution

STATISTICAL TREATMENT OF BACTERIAL DATA

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Results of coli-aerogenes tests on littoral waters near ocean outfalls are highly variable, primarily because currents bring sewage to the sampling stations at varying dilutions and ages, and secondarily because of the rough nature of the testing method.

The attempt to establish correlations of sets of data has required the examination of the nature and significance of patterns of variation, and the way in which bacterial data can be treated by the use of a standard pattern. Interest in the subject, of course, is not new. The examination of the significance and variations of "most probable numbers" here presented approaches the subject from a more rigorous point of view than some previous treatments, and attempts to clarify the subject of variations. The principal statistical technique used is the plotting of logarithms of most probable numbers on probability paper, which is essentially the same technique as has been used by Velz (1), Pierce (2), and others, but there are some significant differences.

General Characteristics of Variations

A set of numbers representing a series of measurements of something, presuming that the results of the measurements are not all identical, shows a pattern of variation characteristic of the method of measurement and of the thing measured. The variation may be due to errors of measurement from what would ideally be a "true value," as in replicate chemical analyses, or it may be due to variations in the thing measured, as, for example, day-to-day variations in the number of eggs from a flock of chickens. As far as statistical procedures are concerned, there is no fundamental difference in the two sources of variation.

If the sources of variation are numerous, small, and random, the pattern approximates what is known as the "normal curve of errors." The correlation of a set of data to this pattern is easily accomplished by use of "normal probability paper." The individual data are arranged in order of increasing (or decreasing) magnitude, and then the accumulated percentages of results are plotted against the values of the variable. A set of data which conforms to the normal curve of errors will produce a straight line on the probability paper.

Various procedures have been proposed for reducing data to a plot on probability paper. The procedure here proposed is simple and sound, and it has proved particularly suitable for the plotting of most probable numbers. It is not contended that this procedure is more "right" than some other methods, except that there is a fault in any method which will not meet certain criteria, one being that it should give a symmetrical curve in the following ideal illustration of tossing pennies.

If a group of eight pennies are tossed many times, there will be a series of results ranging from 0 to 8 heads, with 4 being the commonest result. The *a priori* probabilities of the results are shown in Figure 1 on probability pa-

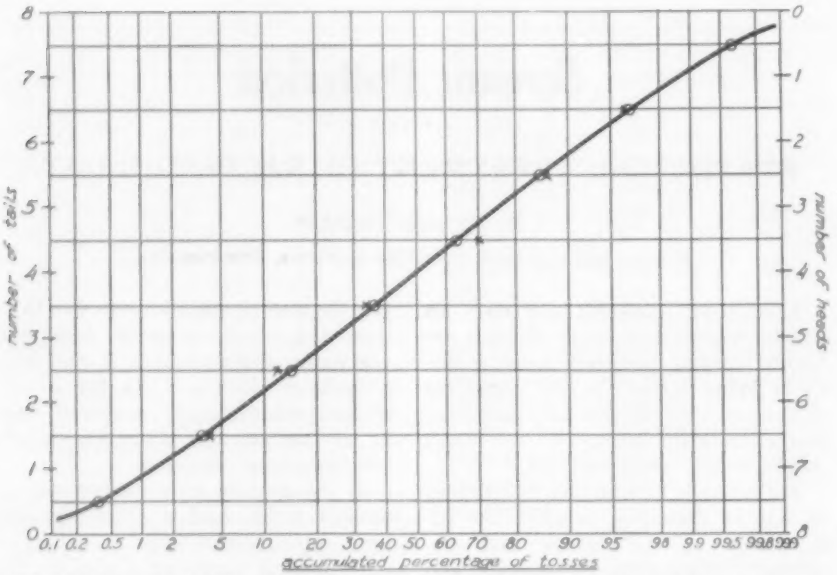

FIGURE 1.—Probability plot of results of eight-penny tosses: O—calculated for an infinite set of tosses. X—results of a set of 50 eight-penny tosses.

per; the actual results of a set of 50 tosses are also shown.* Each result is considered as representing a band of values, and the point on probability paper is plotted at the upper edge of the band. Thus, the fraction of tosses showing results up to and including 4 heads is 63.7 per cent of the total. The number 4 represents a band from $3\frac{1}{2}$ to $4\frac{1}{2}$, and the accumulated total is plotted at $4\frac{1}{2}$. The fractional values have meaning if interpreted as the average numbers of heads in narrow percentage bands in number of sets of tosses.

In any set of data representing a range of values divided into discrete intervals, each plotting point should be above the datum which it represents by an amount equal to one-half of the smallest increment that the data may show.

One may begin at either the low end or the high end of a set of data. If properly plotted, the curve in one case is the mirror image of the curve in the other case. Some published instructions for using probability paper fail to meet this criterion.

Near the center of the plot, the data representing the tossing of 8 pennies correspond very well to a straight line. If this line were extrapolated it would show that occasionally—about one toss in 1,000—the number of heads would be less than zero, and similarly the number would occasionally be more than eight. This of course is not possible. The line is straight only over a limited range; there are upper and lower limits that it cannot pass. This is true of virtually all sets of real data. If a larger number of coins were tossed, conformance to the normal probability equation would be closer.

Many variable quantities are found to approximate the normal curve. Examples in the sanitary engineering field have been pointed out by Velz (1): variable hardness of a water supply, suspended solids content of sewage, and biochemical oxygen demand of sewage.

* Precautions were used to get equal probabilities of heads and tails. Actual pennies tossed on to a hard surface give an excess of tails.

Correlation can only be shown empirically, unless it can be proved that the sources of variation are numerous, that they are all small, and that they are independent and random. At best the pattern is an approximation, and it is valid only over a limited range. It is not valid to assume correlation beyond the range over which it is empirically shown to hold. A hundred tests of the chloride content of a river, for example, cannot be used to indicate the probable maximum or minimum of a thousand tests. Extrapolation of plots which might be made of some quantities, such as suspended solids or B.O.D. of sewage, may show that occasionally—perhaps once in 1,000 years—the concentration would be less than zero. Extrapolations may be made to a limited extent if it is over a range for which conformance has been shown in similar sets of data.

It is important to bear in mind the limitations of the "normal curve of errors" and the use of probability paper, when applied to a variable quantity, but within these limitations there is still an important field of usefulness. Use of probability paper or comparable mathematical procedures permits smoothing of the data, interpolations, moderate extrapolations, calculations of reliability of averages, expressions of coefficients of variation, and estimations of reasonableness of extreme values.

The normal probability paper represents a sort of median pattern which is likely to approximate more kinds of sets of data than any other pattern. There are, of course, many sorts of data which do not conform even approximately. One of these is the annual rainfall of an area. In this case, as in others where the data do not approximate the standard pattern, a modified probability paper can be constructed, provided enough data are available. In other cases a function of the variable may be found which will fit the normal probability paper.

Nature of Most Probable Numbers

Sets of most probable numbers of coli-aerogenes bacteria in shore samples near ocean outfalls show distributions which are not according to the normal curve of errors; this is evident from a glance at such data. Probability paper still may be useful if it can represent some function of the variable, such as the logarithm. There certainly is no theoretical reason to expect that logarithms of most probable numbers would have a distribution according to the "normal" curve, but it has been found by Velz (1) and Pierce (2), and in this study also, that for many sets of bacterial data the logarithms do roughly approximate the normal distribution.

The first problem is to devise a proper method of plotting.

The data used in this study arise from tests which start with the inoculating of pairs of tubes with decimally diminishing amounts of sample from pair to pair, for example, two 10-ml. tubes, two 1-ml. tubes, etc. Where other patterns of inoculation are used, treatment of the data will differ in detail from the treatment here described.

Let it be assumed that the series of diminishing dilutions is not limited, but extends indefinitely both ways. The commonest results are of two types: ++ +− −− and ++ ++ −−. Each pair of signs here represents a pair of tubes, with inoculum amounts diminishing from the left to right. The group +− is understood to include −+. A less common pattern is +− +− −−, and there are others of rare occurrence.

The most probable numbers are:

Type I ++ −− −−
M.P.N. = 2.30×10^x

Type II ++ +− −−
M.P.N. = 6.17×10^x

Type III +− +− −−
M.P.N. = 1.3×10^x

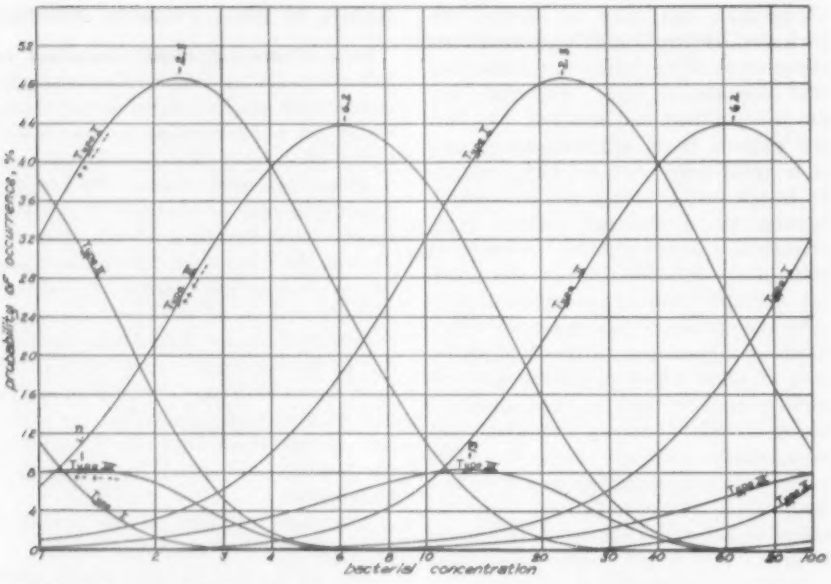

FIGURE 2.—Probabilities of various results in coli-aerogenes tests, assuming unlimited series of pairs of tubes in decimally progressive dilutions.

Calculations of most probable numbers are based on the assumption that a viable bacterium of the type tested for is a certain entity, and that one viable bacterium in a tube leads to a positive finding. On this basis, the probabilities of the various types of results from samples having variable bacterial concentrations are as shown in Figure 2. This shows, for example, that if the concentration is 10 per ml. there is 11 per cent chance that the finding will indicate 2.3 (first Type I curve); 38 per cent that it will indicate 6.2 (first Type II curve); 8 per cent chance that it will indicate 13 (Type III curve); 32 per cent chance that it will indicate 23 (second Type I curve); 7 per cent chance that it will indicate 62 (second Type II curve); and 4 per cent (by difference) for all other possibilities.

All results from samples of variable bacterial concentration should be distributed as follows:

Type I	2.3×10^x	48.4%
Type II	6.2×10^x	41.8%
Type III	1.3×10^x	6.7%
All others		3.1%

Experimental verification of these proportions is not easy because actual tests use only 3 or 4 pairs of tubes, so that the possibilities of observing certain types, such as Type III, is less than the possibility of observing other types. By taking this factor into account it appears that for 5,500 samples from Los Angeles and Orange County beaches the Type III results would be 8 per cent of the total if it were not for curtailment of the series at the ends. Thus the occurrence of this type is a little above the *a priori* probability.

Proportions of Type I and Type II results differ for three major sources of data examined in this study. Two of these sources show proportions close to theoretical; the other shows an abnormally high proportion of Type II. It is believed that reasons for these differences are traceable to analytical

techniques, and to probable deviations from the hypotheses on which the calculations are based.

The proportions of all the other types is definitely higher than the 3.1 per cent that it should be, but the limitations of the data prevent more than approximate estimates.

Use of Probability Paper

In using probability paper for statistical procedures it is necessary to divide the continuous array of possible bacterial concentrations into bands for representation. Type I and Type II results from a natural sequence including most of the results, but what shall be done with the other results?

In considering this problem it may be noted that a sample which has a concentration of 13, and hence is most favorable to this result, will nevertheless yield this result only about 1 time in 12. If a band were left for these results in the array of bacterial concentrations to be plotted, their infrequency of occurrence would cause abnormal irregularities unless many hundreds of tests were available to afford reasonable frequency of occurrence.

The best treatment for these results is to distribute them, half and half, to the two major types on either side. This would be the probable result of re-running such samples (assuming that they could be preserved without alteration until retested).

The other minor types occur more frequently than they should, and it is probable that they are due at least in some cases to contamination, errors, overgrowth of some tubes with competitive organisms, etc. Since the probability of occurrence of these results is small and the probability that the result is erroneous when they do occur is significant, it is thought best that all such results be stricken from the records. It is better to consider the test as a failure in such samples than to keep the questionable results. Alternatively, the next most common result, which may be called Type IV, represented by ++ −− +−, giving 5.0×10^x, may be distributed to the major types as is done for Type III.

After discarding the minor types of results and distributing Type III and possibly Type IV results, there now remains the two principal types.

Some attention has been given to dilution schedules in which three tubes are set in each successive dilution. It appears here, also, that it would be reasonable to distribute minor types to the three major types, which will be +++ −−− −−−, +++ +−− −−−, and +++ ++− −−−, but to discard all results in which three negatives are followed by a positive in a subsequent dilution (as +++ −−− +−−), or in which two or more negatives are followed by two or more positives in subsequent dilutions as (+++ +−− ++−), or in which one negative is followed by three or more positives in subsequent dilution (+++ ++− +++).

In accordance with the principles developed earlier in demonstrating the plotting of occurrences of various results in tossing pennies, each result represents a band of values. On the basis of calculated frequencies of occurrences of types of results, it would appear that the Type I and Type II results, after distribution of Type III results, should theoretically occupy, respectively, 53.5 per cent and 46.5 per

TABLE I.—Data from Santa Monica Bay, Stations 17 and 17A

Bacterial Conc. (M.P.N./ml.)	No. of Results				Plot at
	Actual	Revised	Accum. Total	%	
<0.6	30	30	30	35.7	0.377
0.6	18	18	48	57.1	1.19
1.3					
2.3	17	17	65	77.4	3.77
6.2	4	4½	69½	82.7	11.9
13	1				
23	6	6½	76	90.5	37.7
62	4	4	80	95.2	119
70+	4	4	84		

cent of the concentration scale. Considering that the scale is logarithmic, the dividing points on this basis are calculated to be 3.89, 11.4, 38.9, etc.

Logarithmic probability paper is not generally available with enough cycles for this work. The author has used arithmetic probability paper, and when doing so has ignored the small theoretical difference in band width and has made all bands of the same width. When this is done the divisions or plotting points are 3.77, 11.9, 37.7, etc. These are plotted on even divisions, and a small logarithmic scale from 0.377 to 3.77 ($\times 10^x$) is used for reading points from the lines.

Table I shows the steps in plotting a set of bacterial samples taken several years ago in Santa Monica Bay at Stations 17 and 17A.

Figure 3 shows a graph of this and four other sets of data from Santa Monica Bay. The number of tests in each set ranged from 60 to 150. Figure 4 shows data from Orange County, with about 350 tests in each set. The lines as drawn do not always appear to represent the closest fits, but this is because greater weight is given to points near the middle of the scale than at the end, for the purpose of minimizing the numerical differences between observed and calculated

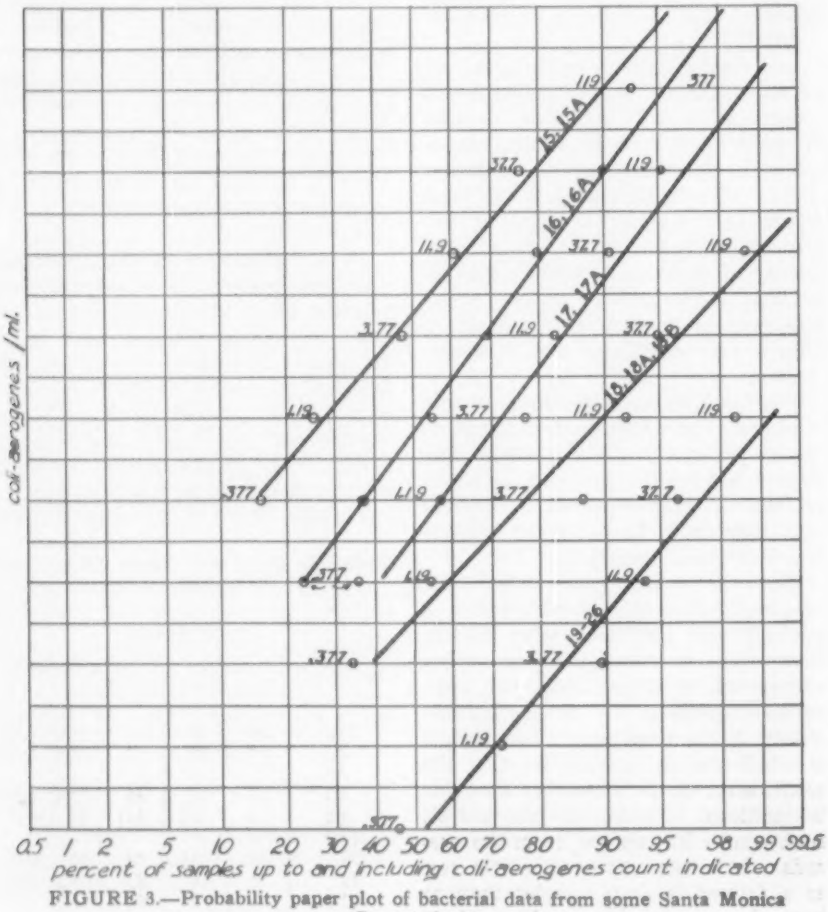
coli-aerogenes / ml.
15, 15A
16, 16A
17, 17A
18, 18A, 18B
19-26
0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5
percent of samples up to and including coli-aerogenes count indicated

FIGURE 3.—Probability paper plot of bacterial data from some Santa Monica Bay stations.

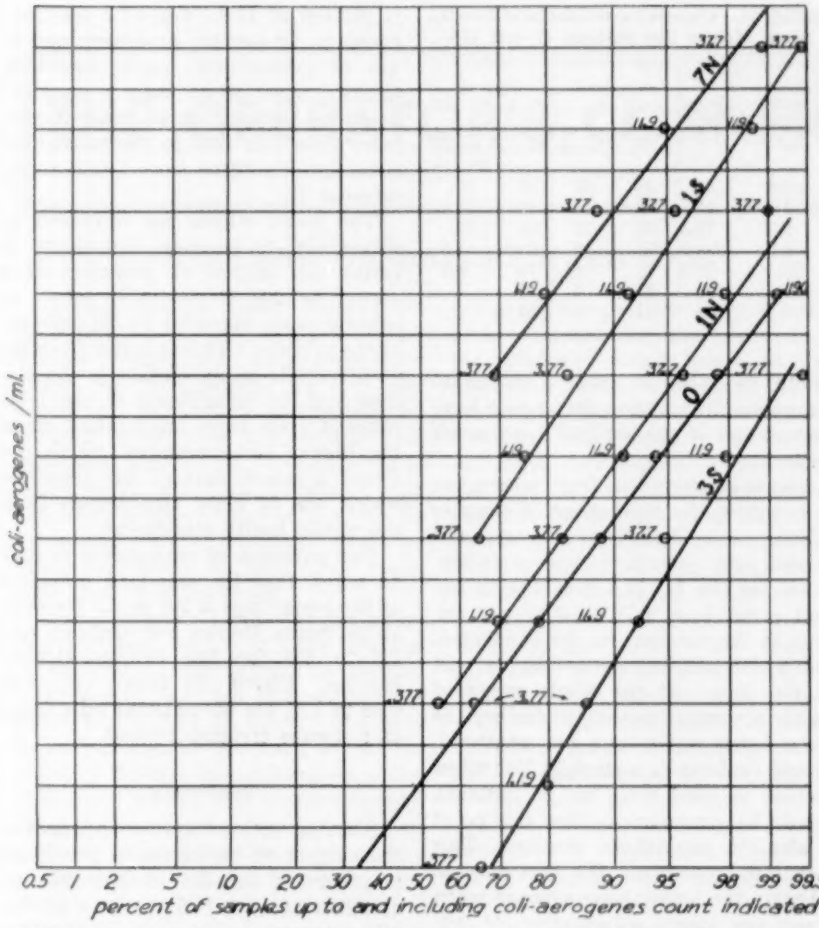

FIGURE 4.—Probability paper plot of bacterial data from some Orange County beaches.

values. Points above 99 per cent are usually given little weight, and no points above 99.5 per cent are considered useful, since one sample more or less makes a large change in the position of the point.

Table II shows a comparison of observed results from Stations 17 and 17A with results calculated from the line as drawn.

Twenty-seven sets of data from Orange and Los Angeles County beaches were plotted. In about 4 of these, including line 18, 18A, 18B, and line 19–26 on Figure 3, the divergence from straight lines is beyond the limits of random scattering. For the other 23 sets, straight lines are adequate and useful representations of the data. For any station, a very large set of data, having points little influenced by erratic variations, would no doubt establish that there is some curvature, which might vary from station to station.

Deductions from Lines on Probability Paper

The lines as drawn (except for those which, as indicated, show unmistakable curvature) represent the best expectation of the distribution of results that

TABLE II.—Observed and Calculated Results, Santa Monica Bay Stations 17 and 17A

Coli-Aerogenes Concentration, (M.P.N./ml.)	From Fig. 3 (%)	Calculated		Observed	
		Accum. Number	No. of Results	Accum. Number	No. of Results
<0.6	41	34	34	30	30
0.6	57	48	14	48	18
2.3	72.5	61	13	65	17
6.2	84.3	71	10	69.5	4.5
23	92.3	77	6	76	6.5
62	96.7	81	4	80	4
70+	100	84	3	84	4

would be obtained from a duplicate set, or the distribution that would have been found if the set had been much larger.

Points can be taken from these plots to ascertain the percentage of samples which, on a long-time average, will exceed any specified concentration. Thus, for the 17, 17A line, the 50 per cent point is at 0.72 M.P.N. per ml. This is the median, or the concentration which will be exceeded 50 per cent of the time. If the whole range of bacterial concentrations, including the lower levels which were not measured, should conform to a straight line when plotted in this way, or, in general, should be symmetrical, then this point is also the logarithmic average. This technique represents the best way to estimate the logarithmic average when there are many all-negative or all-positive samples.

As a further illustration, the 80 per cent point is at 7.4. This is the concentration which, on a long time average, will be exceeded 20 per cent of the time.

One of the standards used by the California State Department of Public Health for judging the quality of bathing waters is the concentration which is exceeded in 20 per cent of the samples. Since the counts are generally determined by the pattern of dilutions studied in this report, this in effect is the number of samples which show a result higher than 6.2. This is plotted at 11.9. Use of a standard based on 10 per ml. as determined by use of probability paper would be slightly more strict than a standard based on the number of tests showing more than 6.2; that is, the number of tests showing 23 or more (with an occasional 13).

The point which has appeared in this study to be most significant in rating the degree of pollution of a station is this 80-percentile point, or concentration exceeded by 20 per cent of the samples. This is better than the 50-percentile point (which is the median and the logarithmic average) because it gives more information about the higher concentrations, which are found a minor part of the time but which are of chief significance from the public health standpoint.

For purposes of comparison it may be noted that the standard deviation of the logarithms is 2.0 to 2.5 for most of the Santa Monica Bay stations, and 2.5 to 3.0 for the Orange County beaches. Pierce (2) found values of 0.86 to 1.25 for the chlorinated effluent of a sewage treatment plant.

Summary

Starting with a rigorous approach to the subject of variations, a procedure is presented for the plotting of logarithims of bacterial data on probability paper.

Twenty-seven sets of data from Southern California beaches near ocean outfalls were plotted. In 23 cases the points approximated straight lines well enough so that the procedure can be used in these cases to obtain more information from limited sets of data than would be possible without this tool.

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THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

FRESHMEN OPERATORS NEED HELP

In the months ahead Donald P. Schiesswohl will be looking over the Corner's mail and endeavoring to gather together material for you—the operator. Don has a background in sanitary engineering, in the sewage and industrial wastes field, through his academic training and his experience with the Florida State Board of Health. So he comes with a genuine interest in plant operation, the men, their problems, and their successes.

The Operator's Corner of the Journal has long been a regular feature of each issue, even though the by-line, "conducted by," has changed several times in the past 14 years. However, from its original inception by Editor "Pete" Wisely, its continuance under "Sandy" Martin, and its development during the past five to six years by "Herb" Orland, the Corner has always endeavored to bring to the reader practical contributions by and for operators.

As has been pointed out many times in the past, this department of the Journal depends upon the continuous participation of plant superintendents and operators in order to fulfill its purpose. The Corner should be made up of practical contributions—by operators—describing their methods of overcoming day-to-day problems. It should include "gadgets", those plant-made devices to save labor or circumvent some minor or major difficulty. It should contain references to experiences and operation reports from which a lesson is to be learned or a pitfall avoided.

During the past several years, Federation membership has grown, as has the number of sewage treatment plants and the personnel engaged in this ever-expanding field. Consequently, there are more freshmen operators today than ever before, in new plants and old. These operators are eager to learn to do their job well and to improve the status of the profession. Some are in responsible charge for the first time of thousands of dollars worth of equipment, and need all the help they can get. They have questions that need to be answered. Only by bringing them out for public discussion can the new operator benefit. Therefore, the problems of the new men and the experiences of the older operators need to find some common ground for free exchange. Here is where your Operator's Corner can serve. Solutions and experiences that may seem commonplace or even routine to you may be just what a fellow operator needs. On the other hand, many of these freshmen operators have new ideas for old problems.

Be it ever so simple, there is nothing like a practical tip or quip from the men in the field. Letters, newspaper clippings, sketches, as well as prepared manuscripts, are always welcome. The headquarters staff will handle any reasonable rewriting, or preparation of drawings.

With *your* help the Corner can continue to serve the operators. We are always interested in hearing from *you* and serving *you* to the best of our abilities.

D. P. S.

DIGESTER OPERATION PROBLEMS IN PENNSYLVANIA *

By John Yenchko

Assistant Regional Sanitary Engineer, Pennsylvania Department of Health, Wilkes Barre, Pa.†

The digestion of sewage solids is one of the important functions of a sewage treatment plant, whether it is by means of an Imhoff tank or a separate sludge digester. In fact, in a primary treatment plant the digester may be considered the heart of the treatment process.

Both the technically trained and the untrained operators in responsible charge of sewage treatment facilities are interested in the digester and its operation. Most treatment plants have digestion processes, and, at some time or other, a problem. Frequently another operator's problem and solution is just the answer to one's own particular problem.

Units Affecting the Digester

The digester is only one unit of the treatment facility, however, and to operate it satisfactorily plant personnel must understand those units which affect it. Some of these units are as follows:

1. Grit chamber—Effective grit removal equipment contributes measurably to the satisfactory operation of the digester. An ineffective unit will load the digester with undigestible solids, which will steal needed capacity and accentuates the problem of removal of solids.

2. Pumping station—A properly designed pumping station will not hold the sewage until it becomes septic. Solids will not be deposited in the wet well due to improper slopes.

3. Primary settling tank—A well-operated primary settling tank will effectively remove the solids, before they become septic. Removal more than once per day is usually required. The use of a time clock control has been considered for intermittent sludge removal. A means of checking the solids content is important, because the transfer of excessive liquid to the digester will impair the efficiency of the digestion process.

Factors Affecting Digestion

Variations in temperature, pH, and solids load cause digester disturbances. Accordingly, they are important factors for good digester control.

Temperature

Most authorities set the desirable temperature range between 85° and 95° F. This does not imply that temperature changes within this range can be made without regard to operating efficiency. When facilities are provided for control of heat in the digester, an optimum temperature should be established and maintained. Recently, emphasis has been placed on adequate heat exchanging facilities and controls.

The organisms responsible for the digestion of sewage solids are quite sensitive to temperature variations. As a result, the digestion process may be impaired through slight temperature changes.

pH

Optimum pH range is considered to be between 6.8 and 8.2, depending to some extent on the chemical characteristics of the water supply. From ex-

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perience it is possible to determine what pH range is most effective for a particular digester.

Records of pH determination on raw sludge, supernatant liquor, and digested solids aid in ascertaining the development of an unsatisfactory condition in the digester.

Alkalinity

The desirable alkalinity range is between 2,000 and 3,500 p.p.m. Sufficient alkalinity must be present in the digester to serve as a buffer in counteracting the acid trend which occurs during the first stages of digestion when raw sludge is added.

If these acids are not controlled, either by the presence of alkaline salts normally in the sewage, by the active digestion process, or by artificial means, the result will be excessive acid production, reflected in a lowering of the pH.

Overload Experiences

Acidification

It is generally recognized that an overload of sewage solids is a primary cause of excessive acidification and liquefaction. Where facilities are available, the quantity of raw sludge transferred to the upset digester may be reduced. In stage digestion, sludge may be transferred from the second-stage digester to the primary digester. Sufficient capacity must still be available to handle the raw sludge. Unfortunately, many older plants are not equipped with duplicate digesters nor do they have flexibility for transferring the digester contents.

The Stroudsburg, Pa., trickling filter sewage treatment plant is an example of an overloaded single-stage, floating cover digester. An attempt is made to maintain the digester at a temperature of 94° F. Digester activity is watched closely, and whenever the pH begins to drop, lime is added to counteract excess acidity.

At present the load to the digester cannot be varied, and without the addition of lime the digestion process is retarded. In this instance, the addition of lime permits continuous digestion and yields well-digested sludge, which can be withdrawn every 5 to 10 days.

Construction of a second digester, with facilities for recirculation and transfer of sludge, should provide ample capacity and flexibility to avoid future digester upsets.

Scum

Scum is a vexing problem, whether it occurs in a separate digester or in an Imhoff tank. A digester without facilities for breaking up scum is subject to the building up of a troublesome layer. Various devices have been incorporated in digesters to minimize this problem. In practice, the operators have learned the shortcomings of their equipment or designed their own means of solution.

At New Castle, Pa., a digester scum problem was solved using a fire department spray nozzle. The nozzle fits on a 2½-in. fire hose and has nine ½-in. holes in a revolving head, giving a strong spray under high pressure. Inserting the nozzle just under the digester roof, through the test holes, produced good results and did not disturb gas production, sludge withdrawal, or the supernatant liquor.

Scum in the digester at the Stroudsburg plant formed a layer 5 to 10 ft. thick that could not be broken up except by complete removal of sludge and scum. During the past three years this condition has made it necessary to empty the digester on at least three occasions. The vexing problem has been that the scum, although well-digested, is of such consistency that it cannot be removed by normal means. Water under pressure has been unsuccessful in breaking up the scum.

An arrangement that has worked satisfactorily in breaking up gas vent scum in Imhoff tanks utilizes a sludge

pump equipped with a flexible hose discharge. Sludge is taken from the bottom of the digester compartment by inserting the pump suction line into the extension of the sludge withdrawal line. By doing this it is not necessary to provide a long pump suction line. The contents within the digestion compartment can be recirculated to the gas vents, breaking up the scum accumulation. There is no displacement of liquor from the digestion compartment to the settling chamber. Transferring the sludge from the bottom of the tank to the top of the gas vents results in a condition that is conducive to digestion of the scum.

Permanent taps in the sludge drawoff lines, ahead of the gate valves which regulate sludge flow to the drying beds, would provide for flexibility of sludge recirculation. These taps could also serve as an aid in dewatering the unit. Interconnection of the sludge piping, with proper valves, would be advantageous.

Sludge Removal

On occasion, sludge removal difficulties are encountered because satisfactory equipment is not available. At least 5 to 6 ft. of hydrostatic head is necessary to move heavy sludge to the drying bed. A pump provided for recirculation could also be utilized for this work. In addition, since the tank may have a depth of from 15 to 20 ft. below the sludge drawoff line, this equipment can be used to facilitate dewatering.

Another advantage for the sludge pump is that sludge could be recirculated within the digestion compartment, thereby moving accumulated sludge from the influent end, where a heavy sludge build-up may occur, to the effluent end. This would eliminate the need for reversing the flow in a long Imhoff tank. The design of channels in a reverse-flow-type Imhoff Tank can be costly and poses a rather difficult hydraulic and maintenance problem in order to avoid the deposition of solids in the channels.

Foaming

Foaming is a problem often accompanying an acid digester condition. A rather interesting experience occurred at Radnor-Haverford, Pa., a mechanical aeration activated sludge plant using vacuum filters for sludge dewatering. In 1949 the digesters began to show evidence of foaming. The condition was corrected by raising the pH through the use of the filtrate from the vacuum filters. Another incident of foaming occurred in April 1954 and again was successfully controlled with the filtrate.

Grit

Grit in a digester has come in for frequent and strong comment by operators who have considerable grit in their sewer systems and either no grit removal facilities, or at best inadequate equipment.

At Clarks Summit, Pa., the solids accumulating at the bottom of the Imhoff tank became so heavy that it was impossible to remove the sludge with the hydrostatic head available. This condition resulted from an excessive amount of grit reaching the sewer system. Since grit removal facilities were not provided, the grit compacted in the bottom. Fortunately, the plant has duplicate Imhoff tanks, making it possible to by-pass one for cleaning purposes.

Cleaning

Emptying either a digester or an Imhoff tank is generally the least desirable type of work at a sewage treatment plant. Where digesters are cleaned at frequent intervals, procedures are established and equipment accumulated so that the task is not too difficult.

Under any circumstances, entering a digester is very unpleasant, whether the solids are removed by bucket, sludge pump, or portable pump. When

a pump is used the solids must be broken up with a hose and washed to the pump suction. In the event sludge is removed by bucket the material must be moved with a shovel, a process that requires by-passing the digester for at least a week. When adequate help and equipment are provided, the operation can be completed in two or three days.

Many times laboratory techniques or facilities enable the detection of impending digester problems. Even with this information available, it is sometimes impossible to cope with the situation due to limited facilities. Consequently, operators will continue to find it necessary to remove the digester contents.

At the Uniontown, Pa., primary treatment plant the task of emptying the digester is facilitated through the provision of two digesters, adequate piping, and pumps, together with ample sludge drying beds. The 45 ft. diameter digesters are equipped with floating covers and are heated by means of copper coils. The side wall height is 22 ft.

Since the drying beds are open and cannot be used in winter, due to poor sludge drying, the sludge is held in the digesters for about 10 months. Consequently, during good sludge drying weather the digesters are completely emptied.

Pumps are required to empty the digester. Two plunger pumps are used to start the sludge moving, then a centrifugal pump is placed on the line and the plunger pumps stopped. When the sludge becomes too heavy for the centrifugal pump, operation reverts to the plunger pumps. As output slows down, due to the heavy sludge, the lines are flushed with supernatant from the second digester.

Flushing operations vary, depending on piping and valve arrangements. Supernatant from a full digester can usually be directed to the suction of the pump that is slowed down by heavy solids and thus allow the pump to clear the lines. The same supernatant can be used to backflush the digester being emptied. Backflushing has a tendency to force solids back from the pump suction inlet. This procedure is repeated until the roof rests on the stop blocks. As soon as the roof rests on the stop block and the water seal is broken, all vents and manholes are opened. A garden hose is used to break down all the scum and sludge that forms between the roof and wall. In doing this the digester is ventilated. After testing for dangerous gases, the tank is entered and a channel washed through the heavy sludge down to the floor at the wall. The sludge at the wall is generally 5 to 6 ft. deep. Once down to the floor, it is an easy matter to wash the rest of the grit and sludge to the pump suction. Using the small hose prevents putting water into the digester faster than the pumps can remove it.

Now that the digester has been emptied, a thorough examination is made of all inside metal work. The heating coils are scaled and hair and lint are removed by hand. Grit is pumped to the drying beds, where it is subsequently removed by farmers and gardeners. Hair, lint, and scale are dumped and covered at the grit dump.

One man can take care of emptying the digester, but two men are always used as a safety measure. Oddly enough, the men rather like the work of removing the sludge and grit. There is a spirit of competition to see who can remove the most sludge and grit in a given time.

Refilling is accomplished by pumping the contents of one of the primary settling tanks into the digester. This has a double advantage—it empties a settling tank for inspection, repairing and painting, and at the same time floats the digester cover. Seed is provided by transferring 3 ft. of sludge from the full digester. Vents and manholes are left open for a day or two to

exhaust all carbon dioxide. After the openings are closed, usable gas is available in about 48 hr.

Inactivating and Reactivating

The question that arises where a single digester is available is how to accomplish its inactivation. Obviously the plant cannot be completely bypassed, therefore solids will accumulate in the settling tanks. If excessive amounts of solids are allowed to accumulate during warm weather, septicity will result, impairing the effluent from the secondary treatment units. Holding these solids for any length of time before pumping them into the digester will make it more difficult to put the digester into satisfactory operation after cleaning.

The generally recommended procedure for starting a digester is to pump the contents of a primary tank into it. Seed should be provided if necessary and the developmet of satisfactory digestion conditions awaited before adding raw sludge, thus avoiding acidification. This procedure is difficult, in the case of a single digester, where bypassing is not permissible. Sometimes it is advisable to add lime to avoid the development of an acid condition.

At Stroudsburg the solids are accumulated in the primary and secondary settling tanks. When the digester is cleaned and ready to go back into operation, this accumulated sludge is pumped into it. Close watch is kept on the pH and the temperature is raised to 90° to 94° F. Digesters have been observed to go back into operation under these unfavorable conditions and to produce a satisfactorily digested sludge in 20 to 30 days.

Sludge Disposal

The thought which occurs when confronted with the need for emptying a digester is where to discharge the sludge. At Stroudsburg, as much as possible of the well-digested material was removed to the glass covered drying beds. The remainder of the material was disposed of by a scavenger. At Clarks Summit the sludge drying beds are adequate to handle the contents from a single Imhoff tank. With an Imhoff tank a secondary problem results in removing undigested solids from the drying beds.

An Imhoff tank at a small housing development was emptied by discharging the sludge to a large excavation. Care was taken to prevent leakage onto the ground surface. After the liquid receded sufficiently, the sludge was covered with dirt and no unsatisfactory conditions resulted.

At Retreat State Hospital, Pa., the Imhoff tank contents were disposed of by discharging them onto a field and plowing under. Health authorities advise against this practice where vegetables that might be eaten raw are planted.

A resourceful operator will look around his plant and find a suitable place to discharge the sludge if his drying beds are inadequate. Many treatment plants utilize sludge lagoons with satisfactory results. The state of digestion or quality of the sludge is an important factor. The Stroudsburg sludge and scum were exceedingly well digested, resulting in no unpleasant odors. It would be inadvisable to put semi-digested sludge or raw sludge on drying beds that were in close proximity to residences. Disposal would then have to be considerably removed or properly covered.

Digester Gas Recirculation

Recirculation and diffusion of digester gas is being observed in a prototype experiment using a fixed cover digester at Erie, Pa. According to reports, the results to date have indicated loadings considerably higher than those used for conventional digesters.

Observation of actual conditions, made through glass covered portholes

in the fixed cover of the digester, showed no apparent accumulation of scum. Raw sludge volatile solids content was understood to be immediately reduced under normal operation. It was reported that the use of accelerated digestion enabled one digester to handle the raw sludge from this primary treatment plant that had previously taxed the capacity of three digesters.

Gaining in moment is the importance of flexibility of digester operation. External heat exchangers, sludge recirculation, points of discharge, supernatant selectors, scum breakers, and now the recirculation of digester gases, all are contributing to a healthier bacterial environment within the digester.

Summary

When digesters are overloaded, there will continue to be some difficulties in their operation. Overloading or temperature changes may result in acidification and foaming. When these conditions appear to be uncorrectable, as in the case of heavy scum accumulations, the only alternative appears to be the removal of the digester contents. The ideal condition is for the operator to detect unsatisfactory conditions before they become impossible to handle. However, this requires keeping continuous and complete records.

Since the old plants must work until such time as improvements are made, means will have to be devised to keep the digesters operating. Treatment plant operators can contribute measurably to the improvement of conditions at present and future sewage treatment plants. Discussions reveal the deficiencies, as well as the innovations of digester operation, and research will provide the advancement in understanding the digestion process.

ECONOMY THROUGH WELDING AT A SEWAGE TREATMENT PLANT *

By John R. Szymanski

Superintendent, Sewage Treatment Plant, New Britain, Conn.

For some time welding has been an integral part of the over-all maintenance program at the New Britain, Conn., sewage treatment plant and has resulted in better, safer, and more economical operations. Through welding, substantial savings have been effected.

This plant serves a metropolitan area of approximately 100,000 people. It was built in 1936 and was designed to give primary and secondary treatment to an average daily flow of 9 m.g.d.

Up to 1941, replacement parts were readily available at reasonable cost, and a substantial reserve of spare parts was maintained. With the advent of World War II, however, it became necessary to use whatever materials and parts were on hand.

Fortunately, it was possible to prolong this reserve up to 1948–49. At that time, the equipment in use was at least 10 years old and demanded closer attention and more service work. Thus a long-range program of maintenance and repairs was instituted in the early part of 1950. The following gives some of the details.

Bar Screen and Triturator

The mechanically cleaned bar screen, for instance, ordinarily requires little

* Ed. Note:—This is a digest of one of the top prize-winning reports in the recent James F. Lincoln Arc Welding Foundation competition for non-industrial business and service establishments (see This Journal, **25**, 12, 1507; Dec., 1954).

maintenance. However, due to the fact that great quantities of sand and grit arrive at the plant, an unusual wear problem occurs on one side of the installation. The metal guide rail and casing wears away rapidly.

To maintain and operate this unit satisfactorily, personnel were faced with the problem of either replacing the entire outside casing with guide rail or repairing the existing unit.

After studying the various factors involved—namely, delivery dates, initial costs, and labor costs, it was found that by hiring an experienced welder and furnishing stock material, the entire job (Figure 1), including one side casing plus guide rail (A), a motor bracket (B), and a sprocket attachment (C), could be completed at a cost 40 per cent below the purchase of new parts and installation costs. In addition, the time element was heavily in favor of the welding procedure.

Attached to the mechanically cleaned bar screen is a standard triturator. The basic purpose of this unit, of course, is to macerate the screenings removed on the bar screen and return these screenings to the flow of sewage for settling and eventual removal.

As previously mentioned, the large quantities of grit and sand arriving at the plant brought about a serious problem in operating this unit. The cutting teeth of hardened steel would

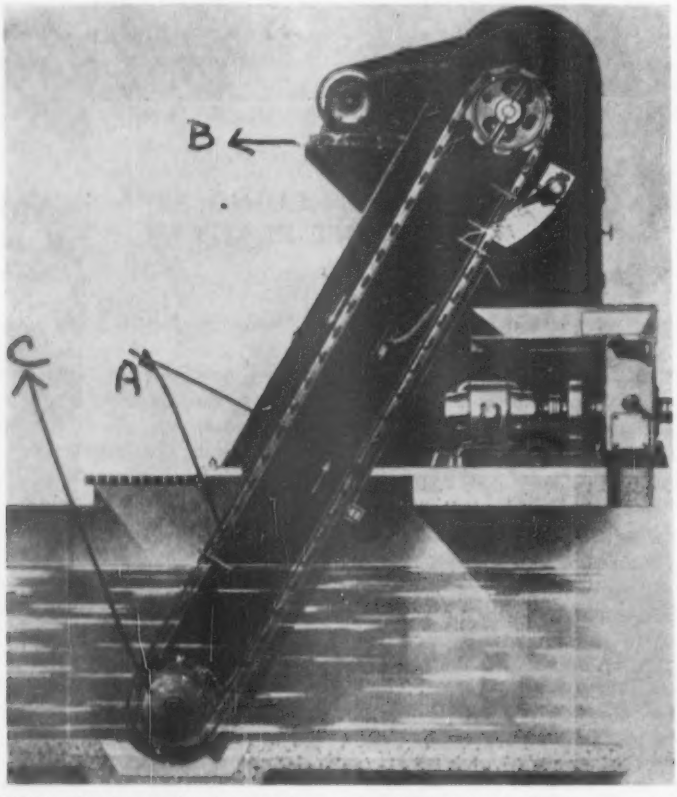


FIGURE 1.—Mechanically cleaned bar screen, New Britain, Conn., sewage treatment plant, showing (A) metal guide rail and casing, (B) motor bracket, and (C) sprocket attachment.

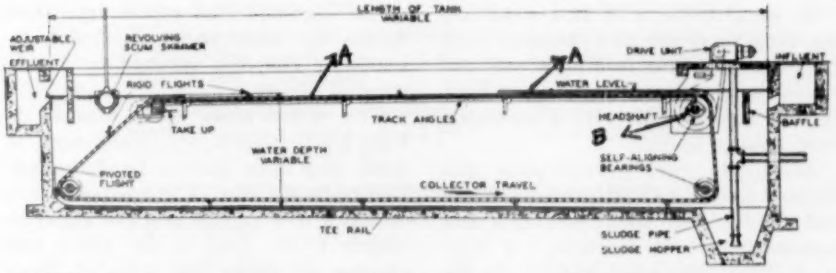


FIGURE 2.—Rectangular primary settling tank, showing (A) collector guide rails and (B) head sprocket.

become dull after two weeks of operation and would require immediate sharpening. After much study and experimentation, it was decided to tip the original cutting teeth with carboloy.

Commercial carboloy tips were welded onto the teeth and have been in good operating condition since 1950. The maintenance cost of sharpening the teeth and replacing them annually amounted to $100. With the welded tips, however, the annual cost is only approximately $20.

Primary Settling Tanks

There are three rectangular primary settling tanks (Figure 2) at the plant, all of standard design. The collecting mechanism is operated continuously and this has resulted in wear of the guide rails (A).

Faced with the problem of replacement, it was decided to retain the original guide rail and to weld hardened steel stock on top of it. Labor and materials for this work amounted to $120 per tank, whereas a new installation would have cost approximately $250 per tank.

A wearing problem occurred on the head sprockets (B). It was found that a welding build-up on the teeth of the sprocket would prolong the life of the sprocket an additional two years.

With the rectangular secondary settling tanks, the same guide rail problem was presented as with the primary tanks. This problem was solved in like manner, with a substantial savings in labor and materials.

Sludge Pumps and Conditioning Tank

In removing sludge from the settling to the storage tanks at this plant reciprocating plunger pumps are used. The material pumped averages about 7.5 per cent solids and is heterogeneous. The reciprocating pistons eventually cause a great deal of wear on their respective cylinders and the heat cracking of the metal becomes an expensive replacement factor.

After much experimentation it was decided to fabricate, weld, and machine these cylinders from heavy-gauge steel pipe.

Standard cast-iron cylinders cost about $40 per unit and would give only about 200 hr. of operation. However, the welded steel units costing approximately $65 each, have given more than 600 hr. of continuous operation.

In the process of sludge disposal the sludge is treated and mixed chemically in a conditioning tank. This is a welded steel, baffled tank 12 ft. by 5 ft. by 4 ft. Although protective coatings have been applied to this unit, holes have been caused by corrosion.

Comparative costs of replacing this tank or weld patching it showed that the life of this unit could be and has been prolonged for the last five years, and that the corrective welding will enable use of this unit for many more years.

In conjunction with this conditioning tank there are two chemical feeders. One, used for feeding a very corrosive chemical, was of the rotary type, of steel construction with a protective hard rubber lining.

After 12 years of operation this feeder was badly disintegrated and several months were spent seeking a new replacement of similar type, but to no avail. Any adaptable unit of similar size would have cost approximately $600. Therefore, after consulting with a reputable welding firm, it was decided to fabricate and weld this unit and then have it rubber lined. An excellent duplicate of the old feeder was obtained at a total cost of $160.

Incinerator Rabble Arms

The application of highly-developed welding principles in the maintenance of the chrome-nickel rabble arms used inside the multiple-hearth sludge incinerator has also resulted in a substantial saving.

The rabble arms, when exposed to high temperatures, eventually tend to bend and have had to be discarded. Before World War II, it was possible to obtain a new rabble arm for approximately $150. Due to the nickel and chrome shortages the price of these arms rose to the present cost of approximately $400 per arm.

The welding company now takes the bent arm, preheats it, cuts it, and then rewelds it into a straight arm which can be used satisfactorily once again. This procedure costs about $75 per arm, resulting in a substantial saving.

There is no question that welding has resulted in a better, safer, and more economically operated plant for New Britain.

SOUTH DAKOTA VOLUNTARY CERTIFICATION PROGRAM

Unanimous adoption of a voluntary certification program by the South Dakota Water and Sewage Works Conference was one of the outstanding events of the Conference's 20th Annual Meeting, September 28–30, 1954. This action culminated a study undertaken more than 10 years ago and delayed due to World War II.

The proposed program, patterned after the Iowa voluntary certification program (see THIS JOURNAL, **25**, 4, 503; Apr., 1953), will be administered by a Certification Committee and will be available to both water and sewage works operators. It is the committee's hope to give the first examinations at the 1955 Conference meeting.

Committee Members

The Certification Committee membership will consist of both a water and a sewage plant operator; a consulting or city engineer familiar with sewage and water; a faculty member of South Dakota State College, the University of South Dakota, or the South Dakota School of Mines engaged in the field of sanitary science; and an elected municipal official currently in office. The Secretary of the South Dakota Water and Sewage Conference will be an ex-officio member.

Four Classification Groups

Certification will be made in four grades based on education and experience; in addition, the sewage treatment plants will be classified to require supervisory personnel who hold one of the corresponding classes of certification according to the following grouping shown on top of page 103.

Class	Certification Grades	Plant Classification
A	College graduate and 1 yr. experience; or high school graduate and 5 yr. experience; or 6 yr. experience.	Complete treatment, population equivalent[1] >10,000.[2]
B	High school graduate or approved course in sewage treatment and 2 yr. experience; or 4 yr. experience.	Complete treatment, population equivalent[1] <10,000.[2]
C	Completion of recognized course in sewage treatment and 1 yr. experience; or 2 yr. experience.	Primary treatment.[2]
D	Same as for Class C.	Lagoons and oxidation ponds.

[1] Population equivalent based on 0.167 lb. of 5-day 20° B.O.D. per capita per day.
[2] Other than lagoons and oxidation ponds.

Fees and Duration

Fees for original certification, renewal, or advancement in all grades will be $1.00 for Conference members and $4.00 for non-members.

Certificates continue in effect for a period of three years. Expired certificates may be renewed, without examination, if application is made within 60 days following the expiration date.

MECHANICAL GATE CONTROL FROM TRUCK DIFFERENTIAL *

By A. M. Medlicott and H. H. Behlmer

Respectively, Plant Mechanic and Superintendent, Water Department, Fargo, N. Dak.

Personnel of the water treatment plant at Fargo, N. Dak., fabricated a geared floor stand (Figure 1) for operating a 36- by 36-in. sluice gate, with a resultant saving of approximately $400. The original gate was of the rising-stem type and operated by a 24-in. hand wheel on the floor stand. It was not geared and the hub of the hand wheel was threaded to engage the 2-in. threaded rising stem. In addition to the initial capital saving, the geared operating stand saves the time of three men, who were normally required to open or close the gate.

The rear axle assembly of a 1931 Model A Ford truck was purchased from a car wrecking company for $35. Both axles, axle gears, spider gears, and spider were removed and not used. The ring gear, differential carrier, and side bearings were used, as well as the drive pinion and bearings. The drive shaft housing was cut off about 1 in. back of the flange where it was attached to the differential housing. A plate was welded over the opening, leaving a hole just large enough to take the pinion drive shaft.

The left side, looking at it from its position on the truck, of the axle housing was cut off about 6 in. back from the differential housing so that it could be inserted in and securely fastened to the top of the old floor stand. The right side of the axle housing was cut off as close as possible to the differential housing and a 3-in. threaded pipe coupling was welded on in its place to provide a connection for the 3-in. pipe and cap to house the rising stem of the sluice gate.

The threaded hub of the hand wheel of the old operating stand was removed and machined so that it could be in-

* Many sewage treatment plant operators could benefit by some low-cost help in operating their sluice gates and valves. This article appeared in the Sept. 1954 *Official Bulletin* of the North Dakota Water and Sewage Works Conference.—Ed.

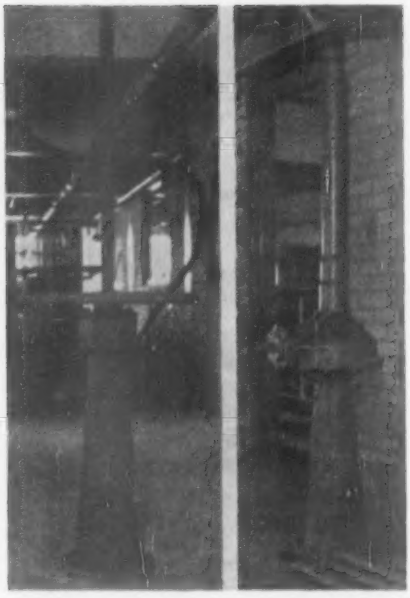


FIGURE 1.—Hand-operated floor stand (left) converted to mechanical gate control (right).

serted inside of the differential carrier where the spider and axle gears had been removed. Four lugs were inserted into the sides of the threaded hub to fit into the openings in the ring gear where the spider had been attached so that it would turn with the ring gear. A small amount of play was deemed necessary to compensate for any slight variation in the vertical travel of the gate stem. The ring gear with the threaded hub attached and the pinion were then replaced in the differential housing and the cover bolted on. The splined end of the pinion drive shaft is used for the operating attachment for the hand-operated crank. The gate now operates so easily that a ¾-in. electric drill with adapter could easily operate the gate by direct drive.

All of the fabrication work was done during odd times when the mechanic's time was not required for other plant duties. A total time of approximately two 8-hr. days was required to do this work and less than one WC tank of acetylene was used. The total cost of the completed floor stand was as follows:

1931 Model A Ford truck parts	$35.00
Acetylene, 1 WC tank	4.47
Labor, 16 hr. at $1.68	26.88
Total cost	$66.35

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the International Airport Activated Sludge Plant, Miami, Fla., for 1953 *

By John S. Whitney, *Superintendent*

The plant continued to produce a satisfactory effluent in spite of a steadily increasing organic and hydraulic load. Originally designed in 1945 to handle 0.06 m.g.d. at 200 p.p.m. average B.O.D., the plant capacity was increased in 1949 to 0.2 m.g.d. at 300 p.p.m. average B.O.D. In 1953, the

* For last previous extract see This Journal, **25**, 7, 857 (July, 1953).

TABLE I.—Summary of 1953 Operation Data, International Airport Activated Sludge Plant, Miami, Fla.

Item	Average
Equivalent population (B.O.D.)	2,040
Rainfall (in.)	63.04
Temperature, air (°F.)	85
Sewage treated (m.g.d.)	0.18
Suspended solids, Gooch (p.p.m.):	
Influent	235
Primary effluent	122
Final effluent	13.7
B.O.D. (p.p.m.):	
Influent	398
Primary effluent	241
Final effluent	14
Reduction, over-all (%)	96
Raw sludge:	
Pumped (g.p.d.)	1,323
pH	6.6
Digested sludge:	
Temperature (°F.)	81
Days to dry	16
Chlorine:	
Used, on effluent (lb./day)	14
Residual, 15-min. contact (p.p.m.)	0.9
Power used (kw-hr.):	
Per day	269
Per lb. B.O.D. removed	.78
Primary tank:	
Settl. sol., influent (ml./l.)	5.2
Settl. sol., effluent (ml./l.)	0.4
Removal (%)	92
pH, influent	7.5
pH, effluent	7.2
Aeration:	
Units used	2
Hours per day	45
Susp. sol., centrifuge (p.p.m.)	977
Settled (%)	44
Sludge vol. index	455
D.O., aerators (p.p.m.)	1.2
D.O., final effl. (p.p.m.)	1.9
Final effluent:	
B.O.D. (p.p.m.)	14
M.P.N.	912
Receiving stream:	
Flow (c.f.s.)	748
Operating costs ($):	
Total for year	11,886.66
Per m.g.	164.70

average maximum flow was 0.23 m.g.d. with peaks of 0.30 m.g.d., resulting in primary clarifier detentions of less than 15 min. The average B.O.D. load was 398 p.p.m.

In addition to the increased load, the plant is plagued at times with metal plating wastes, engine oil, and phenols resulting from chemical toilets used on the planes. Efforts to police the discharge of these wastes have met with some success.

As a result of the overload conditions and treatment difficulties, plans were prepared in 1953 and construction undertaken in 1954 on a high-rate, recirculation type, trickling filter plant. This new facility will replace the activated sludge plant at 36th St. and an overloaded primary treatment plant at 20th St. The new plant was placed in operation during 1954.

In spite of a rainfall of 63 in., twice as much as in 1951, infiltration has been at a minimum.

Operating data for 1953 are summarized in Table I.

13th Annual Report of the Kenosha, Wis., Sewage Treatment Plant for the Year 1953.*

By Frank I. Vilen, *Superintendent*

General

Operating costs for 1953 were higher due to salary increases for the permanent staff of ten. Also, extra labor, costing almost $3,000, was hired during the sludge removal season. Other contributing factors were an unanticipated sum for welfare expenses; replacement parts for the comminutors; and increased pension cost as a result of the salary increase. The cost per million gallons treated was $16.35, an increase of $3.32 over 1952 costs.

The wooden roof on No. 1 digester

* For last previous extract see This Journal, **25**, 6, 734 (June, 1953).

was replaced using Wolmanized lumber. In addition, 30 per cent more hot-water heating coils were installed in this digester. A new floor covering was laid in the laboratory. Throughout the year a strict schedule of equipment inspection and maintenance was carried out. This included overhaul of pumping engines; quarterly inspection of clarifiers, flocculators, and grit equipment; and necessary painting. A yard hydrant and water main were constructed for fire protection and cleaning purposes.

The year 1953 was warmer and drier than 1952. Total precipitation of 22.5 in. was 6 in. less than the plant 13-yr. average. All months except July and December had less than average rainfall. The temperature was higher and the mean for the year was 50.2° F. As a result of the deficiency in precipitation, the daily average sewage flow amounted to 13.6 m.g.d. as compared to 16.2 m.g.d. the preceding year. Treatment efficiencies were somewhat better.

It is interesting to note that 5,000 m.g. of sewage were pumped and treated, resulting in the removal of 3,500,000 lb. of putrescible matter, as dry solids—equal to the load capacity of a 25-car freight train.

Industrial Wastes

Principal manufacturing activities in Kenosha are in the metals industry field. These industrial wastes constitute an estimated 28 per cent of the daily flow. Although the wastes have little organic significance the toxic substances contribute materially to the pollution load.

Copper compounds are the most important toxic substance received at the plant; it frequently is in sufficient quantity to inhibit biological processes. Routine laboratory checks on the sludges indicate an average copper concentration of 0.32 per cent. Other toxic wastes are also closely checked.

Excellent cooperation has been evidenced by the local industries on the discharge of their wastes. Corrective

TABLE II.—Summary of 1953 Operation Data for the Kenosha, Wis., Sewage Treatment Plant

Item	Average
Rainfall (in.)	22.45
Sewage flow (m.g.d.)	13.62
Pop. served (est.)	55,500
Grit removed (cu. ft./m.g.)	0.003
Susp. solids (p.p.m.):	
Influent	136
Effluent	59
Reduction (%)	57
Sett. solids (ml./l.):	
Influent	1.57
Effluent	0.08
Reduction (%)	95
pH:	
Influent	7.4
Effluent	7.3
B.O.D., 5-day (p.p.m.):	
Influent	108
Effluent	50
Reduction (%)	54
Chlorine demand (p.p.m.):	
Influent	7.2
Effluent	4.3
Raw sludge data:	
To primary (gal./day)	5,650
To secondary (gal./day)	7,200
Solids (%)	8.99
Dry solids (lb./day)	9,740
Vol. solids (%)	59.6
pH	6.7
Grease (%)	21.9
Dig. sludge data:	
Solids (%)	14.4
Dry solids, total (tons)	781.2
Vol. solids (%)	45.5
Grease (%)	17.7
Sludge gas data:	
Gas produced, total (m. cu. ft.)	14.64
Per m.g. sewage (cu. ft.)	2,950
Per lb. dry sol. (cu. ft.)	4.14
Per lb. dry vol. sol. (cu. ft.)	6.95
Per cap. daily (cu. ft.)	0.7
Supernatant:	
Dry solids (%)	0.66
Vol. matter (%)	54.1
Operating cost ($):	
Total	3,409.77
Per m.g.	16.35

measures have been applied to the problems brought to their attention; special analyses have been performed when treatment plant laboratory equipment was not adequate; and an awareness exists that an unsolved industrial waste problem is as bad for industry as it is for the community.

Industrial Waste Study

During the year, a laboratory-scale experiment on the effects of a wire-coating compound on digestion was conducted at the treatment plant. The compound had certain manufacturing advantages, but the company officials first wanted assurance that the spent compound would not adversely affect the sludge digestion process. This cooperative experiment afforded an opportunity to predetermine the effects of an industrial waste. Test results indicated that the material would not adversely affect sludge digestion.

Gas Production

Sludge gas production of 6.95 cu. ft. per pound of dry volatile solids represents a considerable increase over the 1952 rate of 5.94 cu. ft. of gas. This is attributable to generally more favorable conditions, such as warmer weather and less loss of organic matter due to storm flows. Less supplemental fuel was purchased and less use made of the standby electric sewage pump as a result of the drier and warmer weather. Approximately $3,000 was saved in fuel and electric power costs. Of the total gas produced, 92 per cent was utilized for pumping and heating.

The 1953 operating data are summarized in Table II.

GASOLINE ENGINE CONVERSION

By A. L. McGee

Superintendent, Sewage Treatment Plant, Chehalis, Wash.

When the gasoline standby engine at the Chehalis, Wash. sewage treatment plant was replaced with a larger diesel engine, the opportunity presented itself to construct an electric generating set. Conversion of the gasoline engine to burn sludge gas, without treatment, was made with a minimum of difficulty.

The engine (Figure 1) drives a 30-kw. generator, which furnishes all the electric power used at the plant and in addition heats the buildings and digesters. Gas consumption averages between 7,000 and 10,000 cu. ft. per day, depending on the electric load.

Engine Modification

The existing carburetor was left on the engine and a ¾-in. pipe was spudded in. To this was attached a safety lock-off valve and a 1-in. solenoid valve. The latter is part of the engine safety control. Two ⅜-in. gas metering valves were installed. One is used for metering digester gas; the other, connected to the intake manifold line from the sealed crankcase, is used to aspirate oil to the valves and guides.

A compression ratio of approximately 7.5 to 1 is obtained. The ignition is advanced 17° before top dead center. The engine starts very well on digester gas; no other fuel is necessary. However, operation is equally satisfactory on propane or gasoline.

Utilization of Engine Heat

A 185° F. thermostat is installed in the water cooling line. The water pump circulates this water through the digester heat exchanger, resulting in better heating on less gas consumption

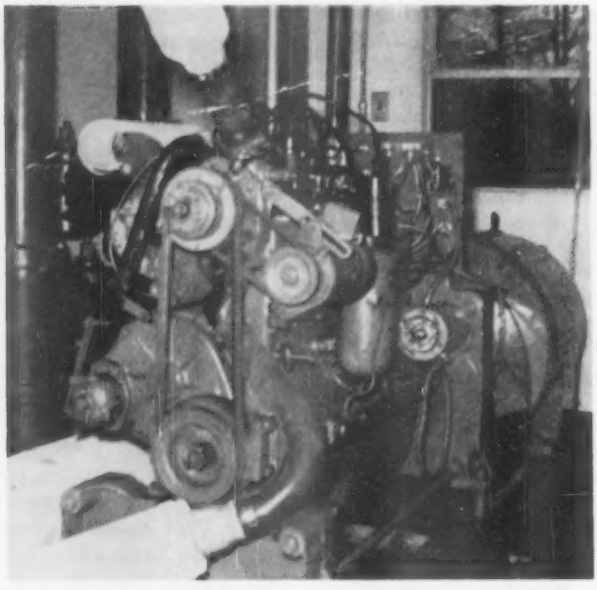


FIGURE 1.—Converted gasoline engine uses untreated sludge gas.

than previously. An interlock is provided between the new arrangement and the original heating equipment. Digester temperature of 117° to 120° F. can be satisfactorily maintained.

Engine exhaust heat is utilized by diverting the exhaust gases through the boiler tubes of the plant heating system and thence, by means of a blower, through a flexible duct to the hollow floating cover on the primary digester.

A dual purpose is served by this arrangement. The top of the digester is heated and moisture condensation, with the resulting corrosion of the structural steel, is prevented. Periodic aspiration of oil through the exhaust blower prevents the formation of rust and scale on the metal digester cover.

Safety Switch

To protect the engine from overheating, oil pressure drop, or generator voltage drop, a safety switch was made from a 6-v. generator cut-out coil, switches, and solenoid (Figure 2).

The engine is started by first bypassing the solenoid valve on the digester gas line. With the engine operating, the 6-v. generator actuates the cut-out coil, thereby closing the circuit to the digester gas line solenoid, which opens the gas supply line.

Normally open hot-water and oil pressure switches close when water temperature exceeds 200° F. or oil pressure drops, grounding the 6-v. generator and de-energizing the cut-out coil. The 110-v. solenoid circuit is opened, causing the gas supply solenoid

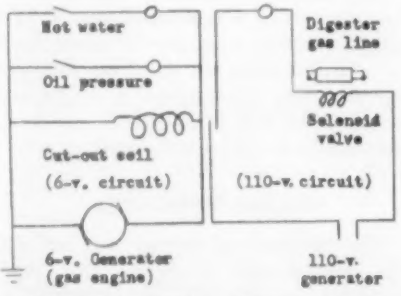


FIGURE 2.—Wiring diagram for gas engine safety switch.

to close, thus shutting off the engine. A drop in 110-v. generator output also will de-energize the gas line solenoid.

Results

With a rating of 24.5 hp. at 1,400 r.p.m., the converted gasoline engine-generator set produces 400 kw-hr. per day. In addition, heating capacity estimated at 350,000 B.t.u. per hour is produced.

Total cost of the engine-generator, including all wiring, was approximately $2,000. The unit has been operating continuously since October, 1953, except for inspections to check wear, at a parts cost of less than $35.

TIPS AND QUIPS

Quarter Century Operators' Club

Frank Woodbury Jones, Chairman of the Quarter Century Operators' Club during the past 13 years, was succeeded at the Federation's Cincinnati meeting (Oct. 11–14, 1954), by Henry Van Der Vliet, Superintendent of the Rutherford, N. J., Joint Meeting.

During the year the active membership roll was increased by the addition of five new members, although the passing of John Simmerman, Pittman, N. J., brought a note of sadness. Twenty-two members were present at Cincinnati for one of the best turnouts in years.

Newly qualified members were Edwin C. McKeeman, Superintendent of Sanitation, Freeport, N. Y.; Carl C. Larson, Chemist, Springfield (Ill.) Sanitary District; Clarence T. Mudgett, Superintendent, Sewage Treatment Plant, Muskegon, Mich.; Andrew Palmer, Superintendent, Plainfield Joint Meeting, Dunellen, N. J.; and Russell S. Smith, currently a public health engineer, USPHS, Cincinnati, Ohio. The roster includes 46 living members and nine deceased.

To be eligible for membership in the Quarter Century Operators' Club, the candidate must have been in full-time resident charge of the operation of a sewage treatment plant 25 years prior to date of his admission to the club. Eligible persons are urged to contact the chairman of the club, whose address is: Henry Van Der Vliet, P. O. Box 281, Rutherford, N. J.

Maintenance Brochure

A new edition of "Good Operating Practices," an illustrated 12-page brochure containing 101 suggestions for maintaining plant buildings and equipment, was recently issued by Johns-Manville. It contains the latest recommendations for getting the best service out of insulations, packings, refactory products, roofings, and friction materials. Copies are available from Johns-Manville, 22 East 40th Street, New York 16, New York.

Air Tool Efficiency

Sewage treatment facilities and sewer maintenance sections large or small may need to make a check of their air tools and lines.

Fittings Losses

Quick-disconnect type air line fittings require regular periodic inspection. After months of service, the rubber washers and metal valves in them can become worn and greatly restrict air passage. The effect is shown in Table I.

Tool manufacturers have standardized their equipment for 90 p.s.i. operating pressure. The delivery power of pneumatic tools is reduced if the pressure falls below 80 p.s.i., and un-

TABLE I.—Tool Efficiency Due to Worn Fittings

Line Pressure (p.s.i.)	Efficiency (%)	
	Old	New
102	5	100
100	27	88
98	80	100
95	48	100
85	41	56
80	25	56

due wear occurs if the pressure goes above 110 p.s.i.

By specifying the best type of fitting, the tool pressure drop through a good quick-disconnect fitting and valve is only 3 p.s.i. or 5 per cent of tool efficiency.

Causes of Power Loss

Improper size and length of hose accounts for considerable power loss, whether on a hand tool or a pavement breaker. The smallest inside diameter rubber hose recommended by air tool manufacturers is 5/16-in. Tests have shown that as much as 1 p.s.i. per foot of hose is lost when diameters are slightly undersize. In some cases it was found that 25 ft. of hose were used when 6 ft. would have been sufficient. A gain of 2 p.s.i. was made by merely uncoiling the hose, thereby reducing the resistance to air flow.

A typical situation which can occur is one in which a ¼-in. hose from an air outlet is plugged to a hose of larger diameter. Here the capacity is limited by the first undersized hose. By merely removing the first hose, tool efficiency was increased 42 per cent. Table II gives examples of gains made by providing proper hose sizes.

TABLE II.—Tool Efficiency Due to Improper Hose Sizes and Lengths

Line Pressure (p.s.i.)	½-In. I.D.		¾-In. I.D.	
	Length (ft.)	Tool Eff. (%)	Length (ft.)	Tool Eff. (%)
106	12′	76%	12′	100%
100	15′	36%	12′	100%
98	14′	46%	12′	90%
94	8′	67%	12′	92%
94	14′	49%	—	—
94	20′	33%	—	—

Mal-Practices

One common mal-practice is to take the tool outlet from the bottom of the feed pipe, tending to make a water trap out of the outlet. Damage can occur to a pneumatic tool through lack of lubrication. As lubricant disappears, small parts and gears begin to wear excessively, resulting in early tool failure.

Adequate hose size to the tool, with ⅜-in. hose as the minimum, together with the shortest convenient length and regular inspection of tools, fittings, and hoses, will materially increase tool efficiency and life.

Iowa Operator Certification

Experience gained in certifying 85 sewage treatment plant operators in four grades has prompted the Certification Committee, in the second annual report of the voluntary operator certification program of the Iowa Sewage Works Association (see THIS JOURNAL, **25**, 4, 503; Apr., 1953), to highlight its objectives and recommendations.

Establishment of a short course by the association's Education Committee and interesting of municipalities in the program, were first steps in accomplishing the objectives. Having deferred the writing of specific rules and regulations pending accumulation of experience, the committee recommended that consideration be given to education and experience requirements, a minimum passing examination grade, and short course credit.

Secretary for the committee is Paul Bolton, Iowa State Department of Health, Des Moines, Iowa.

Federation Affairs

TWENTY-SEVENTH ANNUAL MEETING REPORT

The 27th Annual Meeting of the Federation, held at the Netherland Plaza Hotel in Cincinnati, Ohio, on October 11–14, 1954, was the second largest in number of persons registered, and among the very top from the point of view of program interest and success. Not only was the total registration of 1,103 the second highest in Federation history, but the men's total of 898 and the ladies' total of 205 also were the second highest in their respective categories. Geographically, members or guests were registered from 37 states, the District of Columbia, Alaska, Canada, England, Netherlands, and Switzerland.

The enormous success of the meeting in all its phases is due in large measure to the effort and enthusiasm of the host Ohio Sewage and Industrial Wastes Treatment Conference, as represented by the Local Arrangements Committee headed by Arthur D. Caster. The great attention to planning details by the various local committees greatly enhanced the enjoyable atmosphere of the meeting and made it one that will be long remembered by those in attendance.

The 27th Annual Meeting was convened at 10 AM on Monday, October 11, 1954, by President L. J. Fontenelli. Following the invocation by Rev. Dr. Melvin R. Campbell, and a welcoming address by City Engineer T. J. Montgomery, President Fontenelli commented briefly on Federation activities during the previous year. The report of Executive Secretary-Editor W. H. Wisely concluded the business portion of the opening session.

Technical Program

Topics of broad general interest, as well as many papers on specific pollution and waste treatment problems, characterized the technical program developed by the Program Committee under the chairmanship of F. W. Gilcreas. Both the Operator's Forum and the Industrial Wastes Forum were well attended and received, the lively discussion in each being indicative of the intense interest aroused.

The technical program was as announced in the "27th Annual Meeting Preview" (see THIS JOURNAL, **26**, 9, 1182; Sept., 1954). Technical program papers are to be published in 1955 issues of the Journal, beginning with the February issue.

A highlight feature of the program was the premiere showing of the new edition of the General Electric film "Clean Waters," which was later rerun, by popular demand, for the ladies in attendance.

Entertainment Events

The featured entertainment of the meeting was an excellent amateur stage show in South Seas theme and setting, offered by members of the staff of the Division of Sanitary Engineering, Illinois Department of Public Health.

The Federation Luncheon, held in the Pavillon Caprice, was well attended. Although an unfortunate confusion of arrangements for which he was in no way responsible kept the scheduled speaker from being present, his place was ably filled by E. J. Cleary, Executive Director and Chief

Engineer, Ohio River Valley Water Sanitation Commission, who related his experiences as a participant in the 1954 European Sanitary Engineering Seminar, held in Yugoslavia and sponsored by the World Health Organization and the Rockefeller Foundation.

The Annual Federation Awards Dinner, held in the beautiful Hall of Mirrors on Wednesday evening, October 13, was attended by some 660 members and guests. At the dinner, President Fontenelli presented the annual Federation awards and introduced the new officers. Dancing followed in the Pavillon Caprice to complete a gala evening.

Ladies' Entertainment

Much favorable comment was heard about the excellent ladies' program planned by the local Ladies' Entertainment Committee under the chairmanship of C. H. Allen.

The extremely cordial and gracious spirit of hospitality with which the Ladies' Committee members welcomed and entertained the visiting ladies was deeply appreciated by all.

The Monday afternoon Fashion Show and Tea, including a packing demonstration and talk on air travel, was generously sponsored and financed by the Ohio Sewage and Industrial Wastes Treatment Conference. This provided an excellent opportunity for all the ladies to meet and get acquainted.

On Tuesday, a visit was made to the Procter and Gamble Company's Ivorydale plant, where the manufacturing of soap products and vegetable shortening is carried on under the most modern scientific conditions. On the return trip the buses passed several major points of interest, including the University of Cincinnati, the beautiful railroad terminal station, and the unique downtown church area.

A visit was made on Wednesday to the world-famous Rookwood pottery and the Eden Parks Plant Conservatory, followed by a drive along the Ohio River on the beautiful Columbia Parkway. The day's activities were climaxed by return to the convention hotel for the Federation Dinner and Dance.

Inspection Trip

An impressive entourage visited both the new Robert A. Taft Sanitary Engineering Center of the USPHS at Cincinnati's Little Miami sewage treatment plant. The former houses the main research activities of the USPHS in the sanitary engineering field, as well as providing excellent facilities for presentation of training courses, etc. The latter is the first of four plants intended to serve the Cincinnati metropolitan area.

Manufacturers' Exhibit

New equipment, products and process developments were displayed in an extremely interesting and informative exhibit arranged by the Water and Sewage Works Manufacturers' Association as a co-feature of the Cincinnati meeting. All space allotted for displays was fully utilized to best advantage by the various manufacturers.

Ohio Conference Business Luncheon

The Ohio Sewage and Industrial Wastes Treatment Conference, host for the Federation meeting, held its 1954 Annual Business Meeting in conjunction with a Conference luncheon on Wednesday, October 13.

After President Fontenelli had expressed the gratitude and appreciation of the Federation for the Ohio group's part in making the meeting such a success, the following officers were elected for 1954–5:

Chairman: W. D. Sheets, Worthington.
1st Vice-Chairman: G. A. Pettit, Middletown.
2nd Vice-Chairman: F. Ruck, Troy.
FSIWA Director: G. A. Hall, Columbus.

Secretary-Treasurer: W. E. Conrad, Columbus.

In addition, it was voted to establish new Conference awards to be known as the Dean Stewart Award and the J. W. Ellms Award. The former is to be given annually for outstanding plant operation; the latter, to consulting engineers, state engineers, or municipal administrators for outstanding activity and accomplishment in their respective fields.

BOARD OF CONTROL MEETS AT CINCINNATI

Most noteworthy of the actions taken at the 27th Annual Meeting of the Federation Board of Control at Cincinnati was the acceptance, with reluctance, of the resignation of Executive Secretary-Editor W. H. Wisely; and appointment of Ralph E. Fuhrman, Past President of the Federation, to the position. To provide for the transition, Mr. Fuhrman's appointment was made effective December 1, 1954, Mr. Wisely's resignation being effective January 15, 1955. Mr. Wisely is leaving the Federation staff after 14 years, to become Executive Secretary of the American Society of Civil Engineers. He had been Executive Secretary of the Federation since 1941 and Editor since 1944.

Other actions of the Board included the following:

1. Authorization of the preliminary steps necessary in case it is decided to move the Federation headquarters office to the Washington, D. C., area.

2. Acceptance in principle, and reference to the Executive Secretary for prosecution, of a resolution drafted by the Operators' Forum session urging all Member Associations to initiate and press educational campaigns in their areas on the importance of securing and retaining competent personnel in waste treatment plants.

3. Revision of the Bedell Award rules. In brief, Member Associations will be eligible to name recipients of these awards on a sliding scale based on the number of members enrolled on the previous September 30. Details of the arrangement are given elsewhere in this issue.

4. Suspension of the Hatfield Award competition for 1955.

5. Broadening of the interpretation of the duties of the Industrial Wastes Committee to permit inter-organization effort to coordinate aims and eliminate unnecessary duplication of work.

For the meeting of the 1954 Board on October 10, 48 officers and directors answered roll call. This is thought to be the largest Board meeting to date. Roll call for the October 14 organization meeting of the 1955 Board revealed 33 in attendance.

New Officers

The following officers were elected on October 10 for the terms indicated:

President: David B. Lee, Jacksonville, Fla., to October 1955.

Vice-President: George W. Martin, Green Bay, Wis., to October 1955.

Treasurer: W. W. DeBerard, Chicago, Ill., to October 1955.

Director-at-Large: R. R. Kennedy, San Francisco, Calif., to October 1957.

In addition, Ralph E. Fuhrman, Washington, D. C., was appointed on October 14 as Executive Secretary-Editor for 1955 and 1956. This appointment was made in view of the resignation, effective January 15, 1955, of W. H. Wisely, Executive Secretary since 1941 and Editor since 1944.

Experience outlines for the new President, Vice-President, and Executive Secretary-Editor are given elsewhere in this issue.

1954 Awards

The following honors and awards, as conferred by the Board, were presented or annouced by President Fontenelli at the Annual Awards Dinner on October 13:

Elected as Honorary Members were William Thomas Lockett of Middlesex, England, and Albert Edward Berry of Toronto, Canada, both internationally famous in the Federation's sphere of endeavor.

The Harrison Prescott Eddy Medal was earned by William J. Oswald, Harold B. Gotaas, Harvey F. Ludwig, and Victoria Lynch, of the University of California or the U. S. Public Health Service, for their research contribution "Algae Symbiosis in Oxidation Ponds," Parts II and III (THIS JOURNAL, **25**, 1 and 6, 26 and 692; Jan. and June, 1953).

The George Bradley Gascoigne Medal was conferred on Robert Dittmar Bargman, of Los Angeles, Calif., for his contribution "Organization and Management Control in a Sewage Treatment Plant" (THIS JOURNAL, **25**, 10, 1145; Oct., 1953).

The Industrial Wastes Medal was awarded posthumously to N. H. Sanborn for his contribution "Disposal of Food Processing Wastes by Spray Irrigation" (THIS JOURNAL, **25**, 9, 1034; Sept., 1953).

For his numerous scientific contributions to technical programs and to the Journal, for his long and distinguished service in the Standard Methods and Research Committees of the Federation, and for his guidance to the Federation and support of its interests in the standard methods research program as conducted from 1947 to 1952 with the aid of the National Institutes of Health, Clarence C. Ruchhoft was awarded the 1954 Charles Alvin Emerson Medal.

Nominations for the 1954 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: Arthur N. Beck (Alabama); Merle V. Ellis (Arizona); John Wesley Wakefield (Florida); Max Prüss (German); Gilbert Thorp Cotterell (ISE, England); Leland A. Talbot (Kansas); Charles A. Haskins (Missouri); Theodore C. Schaetzle (Ohio); Bernard S. Bush (Pennsylvania); and Arnold Hoerler (Swiss).

William D. Hatfield Awards for outstanding plant operation reports were presented to Uhl T. Mann, Syracuse, N. Y. (Class II); J. E. Meers, Bloom Township, Ill. (Class II, Previous Winner); and C. W. Christenson, AEC, Los Alamos, N. Mex. (Industrial).

Member Classification

A proposal regarding creation of a new membership classification that would not require the Journal to be taken, referred to the Constitution and By-Laws Committee by the 1954 Board, was again referred to the committee by the 1955 Board on its request that its report and recommendations be held over for the next annual meeting of the Board to allow more careful analysis and study.

Membership

The Secretary reported that the aggregate Active and Corporate membership of the 38 associations comprising the Federation was at a record high of 6,202 on September 30, 1954, a gain of 7.6 per cent for the year. The numerical gain of 440 during the year was the fourth highest in the Federation's history.

The Pennsylvania association, with an increase of 128 members for the contest period, was an easy winner of the 1954 numerical increase prize.

(The record numerical increase of 135 members was set by this same association in 1948.) Other numerical increase leaders were the Texas, Pacific Northwest, Florida, Canadian, and New Jersey associations.

The Puerto Rico association, with a 65 per cent membership increase, won the percentage increase prize for the second year in succession. Contenders for this prize included the South Carolina, Georgia, Texas, and Oklahoma associations.

Financial

The operating budget adopted for fiscal 1955 is balanced at $103,000. Provision is made for all necessary foreseeable costs in the Federation's expanded research activities, the employees' retirement pension plan, and other operational features. In addition, a transfer from surplus to a maximum of $5,000 was authorized to meet possible costs incidental to reorganization which may be required due to the change in Executive Secretary-Editor personnel.

Audited net worth of the Federation at the end of 1953 was $71,909.29. Once again, a modest increase is indicated for the year 1954.

Boston in 1957

Meeting places for the 1955 and 1956 meetings already approved by Board action were Atlantic City, N. J., and Los Angeles, Calif., respectively. Boston has now been officially designated as the 1957 meeting place, with the Hotel Statler as headquarters.

A new invitation received verbally from the Michigan Sewage and Industrial Wastes Association to meet in Detroit was referred to the Meeting Place Committee. Invitations from Member Associations were already on hand as follows: Canadian Institute (Toronto), Pennsylvania (Philadelphia), Central States (Milwaukee), Texas, Rocky Mountain (Denver), and Pacific Northwest (Portland or Seattle).

BEDELL AWARD RULES CHANGED

As a result of recommendations by a special committee appointed to draft a revision of the rules governing the Arthur Sidney Bedell Award, the Federation Board of Control adopted news rules recognizing the size of the Member Associations in the allocation of the number of awards to be authorized. The recommendations as adopted are as follows:

1. That the number of awards per Member Association be as follows:

0 to 34 members	By petition only
35 to 249 members	1 per 3 years
250 to 499 members	2 per 3 years
500 to 749 members	3 per 3 years

but that if any Member Association in the 0 to 34 class increases its membership by 50 per cent and is still under 35 members, it shall by petition be favorably considered for an award before reaching the 35-member status to allow eligibility for one nomination in a 3-year period.

2. That no Member Association nominate more than one recipient per year.

3. That the awards for the succeeding year be made in accordance with the accompanying schedule and reviewed as to eligibility as of the preceding September 30.

Bedell Award Schedule as Adopted by Board of Control on October 14, 1954

Member Association	Members	Past Awards				Nominations	Future Schedule		
	9-30-54	1951	1952	1953	1954	per 3 Years	1955	1956	1957
Alabama	34	1	—	—	1	[a]	—	—	[a]
Arizona	45	1	—	—	1	1	—	—	1
Arkansas	64	—	1	—	—	1	1	—	—
California	552	—	—	1	—	3	1	1	1[b]
Canadian Institute	423	—	—	1	—	2	—	1	1[b]
Central States	618	—	1	—	—	3	1	1	1[b]
Dakota	31	—	—	1	—	[a]	—	[a]	—
Federal	84	—	passed	—	—	1	1	—	—
Florida	182	1	—	—	1	1	—	—	1
Georgia	52	—	—	1	—	1	—	1	—
Germany	38	—	—	—	1	1	—	—	1
Iowa	115	—	1	—	—	1	1	—	—
ISE-England	26	1	—	—	1	[a]	—	—	[a]
ISP-England	133	—	1	—	—	1	1	—	—
Kansas	96	1	—	—	1	1	—	—	1
Kentucky-Tennessee	109	—	1	—	—	1	1	—	—
Louisiana	9	—	passed	—	—	[a]	[a]	—	—
Maryland-Delaware	62	—	—	1	—	1	—	1	—
Michigan	315	—	1	—	—	2	1	—	1[b]
Missouri	39	1	—	—	1	1	—	—	1
Montana	35	—	—	1	—	1	—	1	—
Nebraska	38	—	affil.	—	—	1	1	—	—
New England	347	—	—	1	—	2	—	1	1[b]
New Jersey	223	—	1	—	—	1	1	—	—
New York	615	—	—	1	—	3	1	1	1[b]
North Carolina	120	—	1	—	—	1	1	—	—
Ohio	337	1	—	—	1	2	—	1	1[b]
Oklahoma	50	—	—	1	—	1	—	1	—
Pacific Northwest	271	—	1	—	—	2	1	—	1[b]
Pennsylvania	513	1	—	—	1	3	1	1	1[b]
Puerto Rico	48	—	—	1	—	1	—	1	—
Rocky Mountain	74	—	—	1	—	1	—	1	—
South Carolina	47	—	1	—	—	1	1	—	—
Sweden	73	—	affil.	—	—	1	1	—	—
Swiss	15	—	—	—	1	[a]	—	—	[a]
Texas	201	—	1	—	—	1	1	—	—
Virginia	103	—	—	1	—	1	—	1	—
West Virginia	65	—	—	1	—	1	—	1	—
Total	6,202	8	11	13	10	—	17	15	14

[a] Conditional upon continuing membership.
[b] Year eligible to petition for one nomination.

DAVID B. LEE NEW PRESIDENT

David B. Lee, Director of Bureau of Sanitary Engineering, Florida State Board of Health, became the 15th President of the Federation at the organization meeting of the 1955 Board of Control, held at Cincinnati, Ohio, on October 14, 1954.

After graduating from the University of Florida in 1932 with the degree of Bachelor of Science in Engineering, Mr. Lee held positions as field engineer, district engineer, and malaria control engineer with the Florida State Board of Health. During this period (in

1937) he received a Master of Science in Engineering degree from Harvard University.

In 1941 he was appointed to his present position as Director of the Bureau of Sanitary Engineering. His service in the Sanitary Corps, U. S. Army, from 1942–5 included command of the 4th Malaria Control Unit in New Guinea (1943–4) and specialist in malaria control engineering with the Institute of Inter-American Affairs. Since 1948 he has been a special consultant to the USPHS on sanitary engineering problems, and was a member of the United States delegation to the Second World health Assembly in Rome (1949).

Mr. Lee is a Registered Professional Engineer in Florida, a member of the National Research Council Committee on Sanitary Engineering and Environment, a member of the Conference of State Sanitary Engineers (Chairman 1948–9), and a member of the Florida Sewage and Industrial Wastes Association, having served the last organization as its first President (1941–2).

He also is a member of the Florida Engineering Society (President, 1952–3), the American Public Health Association, the Florida Anti-Mosquito Association (President 1946–7), the Jacksonville Engineering Professions Club (President 1946), the American Water Works Association (Director 1948–51), the Florida Committee on Water Supply and Sewerage Education (Permanent Chairman), and the Florida Public Health Association (President 1950–1). He also is a member of several general engineering societies. In addition, he is the recipient of several engineering society awards, including the Federation's Kenneth Allen Award (1948), the Florida Engineering Society Award (1949), the Centennial Award of the University of Florida (1953), and membership in Sigma Tau.

Besides serving as the Florida Director on the Federation Board of Control (1946–9), Mr. Lee also served as a Director-at-Large (1952–3), and as Vice-President of the Federation (1953–4). He has been a member of the Legislative Analysis, Emergency Planning, Executive, and Meeting Place Committees of the Federation. At present he is a member of the Executive, Finance, Joint Policy, Meeting Place, and Honorary Membership Committees.

GEORGE W. MARTIN ELECTED VICE-PRESIDENT

George W. Martin, Chief Engineer and Superintendent, Green Bay (Wis.) Metropolitan Sewerage District, was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 10, 1954. As an operating superintendent for 19 years, he is personally acquainted with the problems and requirements of plant operators and administrators; his professional activities give him an insight into and appreciation of the reasons behind current Federation objectives and future aspirations.

Prior to appointment to his present position in 1935, Mr. Martin had been resident and design engineer on construction of municipal works throughout the Midwest. It was as resident engineer for its construction that he gained his intimate knowledge of the Green Bay plant. He holds a Bachelor of Science degree and a Civil Engineer degree from the University of Wisconsin, and a Professional Engineer's license in Wisconsin.

Besides holding membership in several general engineering societies, Mr. Martin is a member of the Central States Sewage and Industrial Wastes Association (President 1941–2) and the

Conference of Wisconsin Sewage Works Operators (President 1941). He has served the Federation as Director (1949–51) and as a member of the Sub-Committee on Sewage Treatment Plant Design (1953–5), the Convention Management Committee (1950–1), and the General Policy Committee (1948–9), and has been a recipient of the Federation's Kenneth Allen Award (1946) and the William D. Hatfield Award (1949). He currently is a member of the Executive Committee and the Meeting Place Committee.

RALPH E. FUHRMAN APPOINTED SECRETARY

Among the major actions taken by the 1955 Federation Board of Control at its organization meeting on October 14, 1954, was the appointment of Ralph E. Fuhrman, formerly Deputy Director, Department of Sanitary Engineering, Government of the District of Columbia, to the position of Executive Secretary-Editor of the Federation. Dr. Fuhrman's appointment was made effective December 1, 1954, to allow for a transitional period before the January 15, 1955, effective date of W. H. ("Pete") Wisely's resignation.

Dr. Fuhrman holds the degree of Bachelor of Science in Civil Engineering from the University of Kansas, of Master of Science in Engineering (Sanitary) from Harvard University, and of Doctor of Engineering from The Johns Hopkins University. He is a Registered Professional Engineer in Maryland and the District of Columbia.

Following graduation from the University of Kansas, Dr. Fuhrman instructed at that school in applied mechanics and served as City Sanitary Engineer, Springfield, Mo.; Assistant Public Health Engineer, Missouri State Board of Health. In 1937 he went to Washington, D. C., as Assistant Superintendent of the District of Columbia Sewage Treatment Plant. He became Superintendent in 1942, and in 1953 was made Deputy Director of Sanitary Engineering for the District of Columbia Government. He also has been recently a Lecturer in Civil Engineering at The George Washington University.

Dr. Fuhrman is a member of the Maryland-Delaware Water and Sewerage Association (President 1950–1); the American Water Works Association; the American Public Health Association, in which he is currently chairman of the Committee on Sewage Disposal; and the American Society of Civil Engineers, in which he is currently Vice-Chairman of the Sanitary Engineering Division Executive Committee.

He has served the Federation on the Membership (1934–7), General Policy (1942–9), War Service (1943–4), Legislative Analysis (1946–9), Executive (1949–52), Meeting Place (1949–52), Finance (1950–52), Nominating (1950–), Honorary Membership (1950–), and Joint Critical Materials (1950–) Committees. He also served on the Board of Direction at three different times, representing the Missouri Water and Sewerage Conference in 1932 and again in 1934–7, and the Maryland-Delaware Water and Sewerage Association in 1946–8. He then served as Vice-President (1949–50) and President (1950–1) of the Federation. He is currently a member of the Publications, Joint Policy, Meeting Place, Convention Management, Honorary Membership, Nominating, Joint Critical Materials, and Sewage and Industrial Wastes Practice Committees.

Reviews and Abstracts*

Polarographic Determination of Dissolved Oxygen in Dilute Sulfite Waste Liquor. By H. S. Levine and O. J. Williams. *Anal. Chem.*, **26**, 1297 (1954).

Sulfite waste interferes with the determination of dissolved oxygen by the Winkler technique because of free sulfur dioxide in the wastes. It is recommended that the polarograph measurement be made in a dilute solution of sulfite waste liquor at pH 4.1 with a 0.6-v. potential between the electrodes. The technique has good precision, but it is necessary to use several steps to calibrate the instrument.

R. S. Ingols

Colorimetric Determination of Zinc and Copper with 2-Carboxy-2′ hydroxy-5′ sulfoformazylbenzene. By R. M. Rush and J. H. Yoe. *Anal. Chem.*, **26**, 1345 (1954).

A simple direct test for copper is described using a solution of 2 carboxy-2′-hydroxy-5′-sulfoformazylbenzene (Zincon) at pH 5.0. The same reagent can be used to determine zinc directly at pH 9.0. The copper gives the same color as the zinc at pH 9.0, but the zinc produces no color at pH 5.0.

A number of metal ions interfere, including aluminum, cobalt, manganese, chromium, and nickel. A method is described to eliminate the interferences by using an ion exchange column.

R. S. Ingols

Studies of Waste Water Reclamation and Utilization. By A. F. Bush and S. F. Mulford. State Water Poll. Control Board, Sacramento, Calif. Publ. No. 9 (1954).

This report covers the determination of (a) relationship of underground water pollution to methods and rates of spreading and percolation of reclaimed waste waters; (b) the effects on underground water pollution of increasing the rates of percolation of reclaimed waste waters by means of cropping and vegetation, additives to top layers of soil, forced irrigation, or other means; (c) degree of contamination and/or pollution of a variety of truck crops on maturity where the reclaimed waste waters from various sources, including sewage and industrial wastes, have been applied to the crops and spreading areas by flooding, spraying, or other means; and (d) the extent of odor or other nuisances which may result from such procedure.

The report contains many charts and tables, not only for California, but also for other states.

The authors conclude that sewage is a resource in many localities and is used in some parts of the United States for recharge of aquifers.

The distance contamination and pollution will travel through soils appears to be a function of the percolation rate. Initial rates of percolation appear to range from 0.5 to 200 ft. per day for spreading operations and depend on various factors. Effluents from sewage plants providing only primary treatment, when spread on crops or land, appear to produce high initial coliform bacteria counts in surface soil and on foliage wet by the effluent.

The authors recommend that waste water should be considered a water resource and that further studies be made of rates of percolation and degree of treatment required to handle the pollution load, also to remove salts (particularly sodium and boron) from sewage and industrial wastes. Useful references and a bibliography are furnished.

Langdon Pearse

Recovering Silver and Acetate Base—Eastman Kodak Company, Rochester, N. Y. *Chem. Proc.*, **17**, 9, 10 (1954).

Recovery of silver and acetate base from waste film by the Eastman Kodak Com-

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

pany is a problem of processing about 300,000 lb. of scrap film per week and recovering about 4,000,000 oz. of silver a year, worth approximately $3,500,000. Four Cowles Ultrafast Dissolvers (each 6,000-gal. capacity) were installed. Gelatine (containing silver) is dissolved in a solution of dilute caustic soda at 190° F. A 3,000-lb. batch of chopped sorted film is pumped into each unit. Film base is also recovered, rinsed, and bleached. The first step, removing the emulsion from film base, has been reduced to 1.5 hr.

LANGDON PEARSE

Getting Sulfides Out of Waste Water. *Chem. Eng.*, **61**, 9, 132 (1954).

The Texas Gulf Sulphur Co. has developed and put in operation at its new Spindletop Dome mine a process for treating 1 m.g.d. of waste water containing 270 p.p.m. soluble sulfide and 74,000 p.p.m. sodium chloride. Sulfurous acid gas made by burning sulfur is injected into the waste. The waste water is pumped to a gas separator in which hydrocarbons containing hydrogen sulfide are removed. The effluent passes to a reactor, where it is detained for 2 hr. at pH 7.8. Lime slurry is then added to bring the pH to 7.2. Alum is then added as waste water passes to the flocculators, and thence to final separation in two 50-ft. diameter clarifiers. The effluent is said to be stable, neutral, and clear salt water.

LANGDON PEARSE

Problems that Concern the Engineer in the Treatment of Trade Effluents—A Discussion. *Jour. Inst. San. Eng.*, **53**, Part 3, 95 (July, 1954).

G. T. Cotterell summarizes the problem in Great Britain. Others urge a closed circuit for cutting oils, emphasize pretreatment, express concern with the attitude of local authorities in banning discharge of industrial wastes to sewers, favor cooperation with industry and urge the appointment of competent trade effluent inspectors, express surprise at any general delivery of untreated wastes to a sewer system particularly when acid, refer to an earlier memo by Cotterell and emphasize the flexibility of modern sewage treatment and the success with a sliding scale of charges for handling industrial wastes, laud research and recovery of waste material, and urge intelligent cooperation with industry. LANGDON PEARSE

Nitrate Treatment of Waste Waters Containing Hydrogen Sulfide. BY E. SCHULZE. *Gas- u. Wasserfach*, **95**, No. 14 (1954).

25 kg. of powdered $NaNO_3$ reduced H_2S from 12.8 to 9.3 p.p.m. when spread as a powder over the surface of a 4,000-cu. m. duck pond 1.5 m. deep. On a later date, 30 kg. of $NaNO_3$ reduced H_2S from 3 p.p.m. to 0 p.p.m. and 27 p.p.m. B.O.D. to 19 p.p.m. 54 and 270 p.p.m. $NaNO_3$ added to sewage reduced the B.O.D. from 175 p.p.m. to 114 and 62 p.p.m., respectively, in six days. The species and physiology of the bacteria responsible for nitrate reduction are reviewed.

PETER K. MUELLER

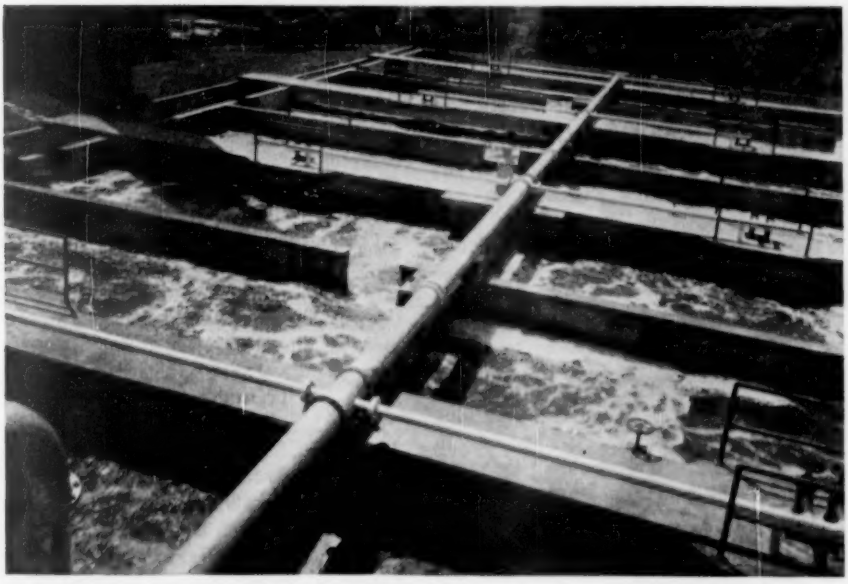
Effect of Cabin Cruiser Waste Discharge on a Small Harbor. BY W. T. INGRAM AND A. DIACHISHIN. *Proc. Amer. Soc. Civil Eng.*, **80**, Separate No. 455 (June, 1954).

Weekend surveys covering bacteriological samples and observations of floating material were made in a small harbor during the 1953 yachting season. The data are tabulated to enable a study of the effects of boat population, recreational activities, periods of the day, and tides.

Twenty per cent of the samples showed pollution levels equal to or greater than that allowed for shellfish waters. Boat concentration had no relation to results, the activity on them being most important. No marked accumulative effect was noted. The most objectionable feature was the finding of floating solids of boat origin, which one-third the time contained fresh sanitary sewage solids.

A short resume is included on regulations of a number of State Health Departments covering discharge of wastes from boats.

WILLIAM A. HASFURTHER



Diffusair Aeration Increases Plant Capacity

The replacement of mechanical aeration equipment with Walker Diffusair units enabled Birmingham, Michigan, to substantially increase the capacity of their aeration tanks without the expense of constructing additional tanks. Note that this installation is now cross roll circulation giving excellent tank roll without the use of top deflecting baffles.

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Proceedings of Member Associations

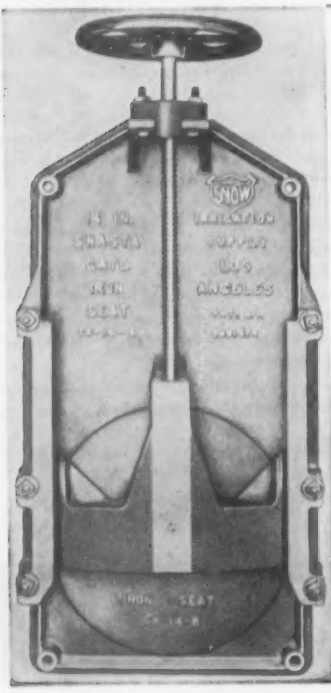
INSTITUTE OF SEWAGE PURIFICATION

The 1954 Annual Conference of the Institute of Sewage Purification was held at Blackpool, England, on June 21–5, 1954. The registration of 650 established a new record for attendance at the meeting.

Papers of technical interest included the following:

Symposium on "The Evolution and Development of the Activated Sludge Process of Sewage Purification in Great Britain," comprising papers on "The Evolution of the Activated Sludge Process," by William T. Lockett, Chief Chemist, Middlesex County Main Drainage Department; "The Development of the Process Using Diffused Air, with Special Reference to the Manchester Pioneering Work," by William T. Locket; The Birth of the Simplex Process at Bury Sewage Works," by Joshua Bolton, former Manager, Bury Sewage Department; "The Development of the Bio-Aeration Process," by J. H. Edmondson, General Manager and Engineer, Sheffield Corporation Sewage Disposal Department; "The Development and Application of the Partial Activated Sludge Method of Treatment at Birmingham," by F. C. Vokes, Engineer, and S. H. Jenkins, Chief Chemist, Birmingham Tame and Rea District Drainage Board; "The Operation of Diffused Air, Simplex and Bio-Aeration Plants at Manchester Sewage Works," by Clarence Jepson, former General Man-

(*Continued on page 28a*)



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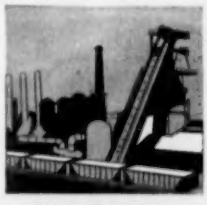
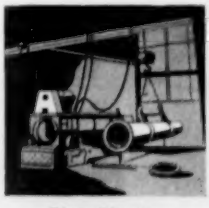


Blast Furnaces



Pipe Plants

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ager, Manchester Corporation Rivers Department; "The Improved Bio-Aeration Plant," by J. H. Edmondson; "Application of High-Intensity Simplex Aeration Cones at Bury Sewage Works," by G. R. C. Marsden, Manager, Bury Sewage Department; and "The Large-Scale Application of the Diffused Air Process at the Mogden Works," by C. B. Townend, Chief Engineer, Middlesex County Main Drainage Department.

Some Aspects of the Law and Practice Relating to River Pollution Prevention," by G. E. Walker, Secretary and Solicitor, Thames Conservancy.

Inspection trips were made to the several pumping stations of the Blackpool sewer system, the Withington sewage treatment plant of the Manchester Corporation and the Davyhulme sewage treatment plant of the Corporation.

William T. Lockett, Chief Chemist, Middlesex County Main Drainage Department, was presented a certificate of Honorary Membership in the Federation.

New officers of the Institute were elected as follows:

President: Arthur Key, London.
Vice-President: Harold Taylor, Dukinfield.
Secretary: Arnold Kershaw, Slough.

W. F. FREEBORN,
Secretary

IOWA SEWAGE WORKS ASSOCIATION

The 36th Annual Meeting of the Iowa Sewage Works Association was held at the Hotel Russell-Lamson, Waterloo, Iowa, September 14–16, 1953. Total registration for the meeting was 118, including 9 ladies.

Papers presented at the meeting included the following:

"Survey of Industrial Wastes in

(*Continued on page 30a*)

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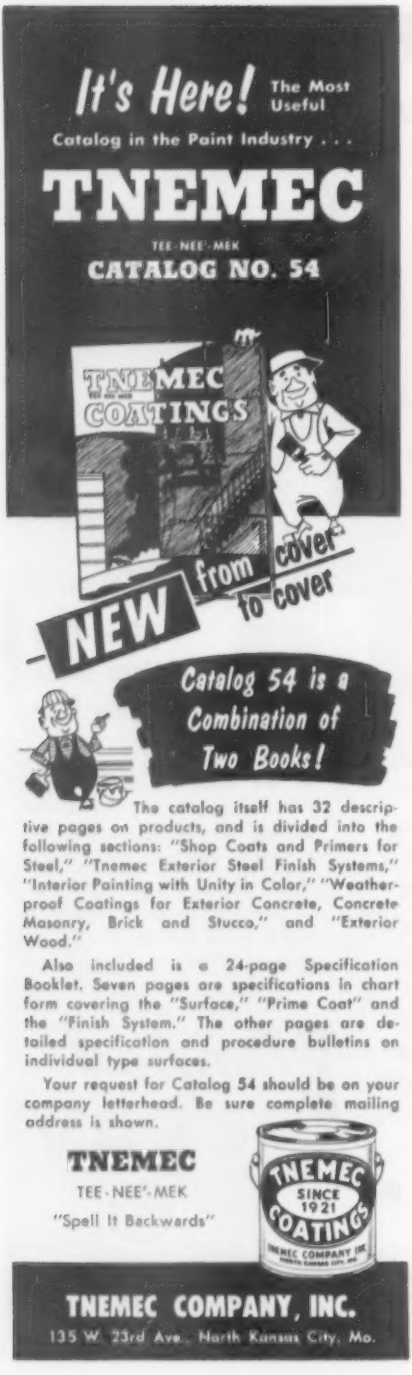
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Also included is a 24-page Specification Booklet. Seven pages are specifications in chart form covering the "Surface," "Prime Coat" and the "Finish System." The other pages are detailed specification and procedure bulletins on individual type surfaces.

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Iowa," by C. D. Mullinex, Howard R. Green Engineering Co., Cedar Rapids.

"Modern Methods of Cannery Wastes Treatment," by Helmer Monson, Green Giant Co., LeSueur, Minn.

"Charges for Industrial Wastes Treatment," by A. J. Steffen, Wilson & Co., Chicago, Ill.

"Management's View," by Paul L. Twedt, John Morrell & Co., Ottumwa.

"What Does Your Plant Effluent Do to Your Stream," by George R. Wimmer, Water Biologist, Division of Public Health Engineering, Iowa Department of Health.

"Sewage Treatment and Stream Standards," a discussion by a panel comprising P. F. Morgan, Professor of Sanitary Engineering, Iowa University; P. J. Houser, Director, Division of Public Health Engineering, Iowa Department of Health; Leo Holtkamp, Superintendent, Sewage Works, Webster City; and Karl Hirlinger, John Morrell & Co., Ottumwa.

"Laboratory Control and Plant Records," a discussion by a panel comprising H. S. Smith, Stanley Engineering Co., Muscatine; Paul Bolton, Division of Public Health Engineering, Iowa Department of Health; Ralph Briley, Chief Operator, Sewage Treatment Plant, Ames; and E. R. Baumann, College of Engineering, Iowa State College.

"Operation and Maintenance of Electric Motors," by R. H. Wareham, Louis Allis Co., Milwaukee, Wis.

"Operation and Maintenance of Pumps," by P. Stempel, Fairbanks-Morse Co.

"Paints," by E. J. Sirmay, Tropical Paint Co., Cleveland, Ohio.

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Plug Valve Actuators—New 8-page Bulletin 3020 describes plug valve actuator mechanisms and mountings, and gives engineering data.—Ledeen Manufacturing Co., 1600 S. San Pedro St., Los Angeles 15, Calif.

Adjustable Dock Ramp—New catalog sheet describes features and installation procedures of manual floating hydraulic adjustable ramp for loading docks.—Rowe Methods, Inc., 2534 Detroit Ave., Cleveland 13, Ohio.

Concrete Pressure Pipe—Fully illustrated 24-page booklet on "The Story of Concrete Pressure Pipe" deals with the history of concrete pipe and the present application of this experience in prestressed concrete pressure pipe.—Price Brothers Co., 1932 E. Monument Ave., Dayton 1, Ohio.

Submerged Combustion—New 17-page manual describes use of submerged combustion heating and concentration equipment in various industries.—Submerged Combustion Co. of America, Inc., P. O. Box 267, Hammond, Ind.

Telemeters—Various systems of wire and wireless telemetering, as well as the apparatus and accessories involved, are described in 44-page Bulletin M1710.—Bristol Co., Waterbury 20, Conn.

Joint Sealer—A waterstop installed after concrete is placed is described in a new booklet on IGAS joint sealer.—Sika Chemical Corp., Passaic, N. J.

Cable Electric Hoist—Bulletin CQ describes cable electric hoists in capacities from 500 to 4,000 lb. with various types of suspensions.—Coffing Hoist Co., Danville, Ill.

Pneumatic Controllers—Catalog 53–10 (12 pages) gives engineering data on pneumatic controllers for process variables.—Fischer & Porter Co., 148 Jacksonville Rd., Hatboro, Pa.

Comminutors—Fully illustrated 28-page Manual W–317–B17 gives complete engineering data on comminutor selection, installation, operation and maintenance.—Worthington Corp., Harrison, N. J.

Synthetic Resin Coatings—New 8-page bulletin describes various synthetic resin protective coatings and their applications.—Metalweld, Inc., Scotts Lane and Abbottsford Ave., Philadelphia 29, Pa.

Hydraulic Valves—Cushioned hydraulic valves in 2-in. to 36-in. sizes are described in Bulletin W8–A.—Golden-Anderson Valve Specialty Co., 1249 Ridge Ave., Pittsburgh 33, Pa.

Chemical Feeders—Catalog 70–50 describes small, low-cost feeder for metering, controlling, mixing and dispensing small quantities of liquid chemicals.—Fischer & Porter Co., 149 Jacksonville Rd., Hatboro, Pa.

Dall Flow Tubes—New 16-page Technical Bulletin 115–L3 describes the new short differential-producing metering device having the lowest permanent head loss of any known velocity-increasing differential producer.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

Intercom Systems—Industrial paging and intercom systems are described in new flier.—Executone, Inc., 415 Lexington Ave., New York, N. Y.

Gate Valve Operators—Power gate operators, both self-powered and from truck take-off, are described in Bulletin 200.—Payne Dean & Co., Clinton, Conn.

Ion Exchange Units—Ion exchange units for industrial wastes treatment and byproduct recovery from plating wastes are described in Technical Bulletins P–112, P–114, P–115 and P–117.—Frederic B. Stevens, Inc., 1800 18th St., Detroit 16, Mich.

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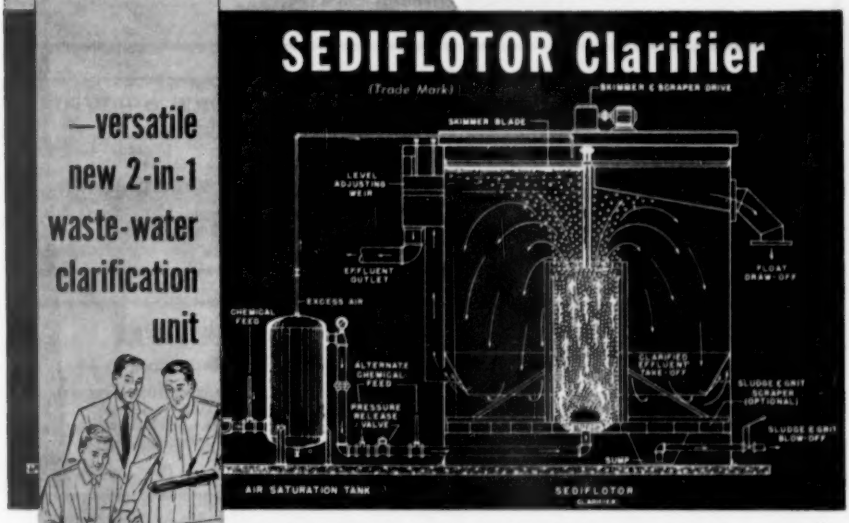

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